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RECENT DEVELOPMENTS IN THE STUDY OF DENTAL CARIES

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DENTAL caries, commonly known as decay of the teeth, is the most prevalent disease of mankind. Since there has been no known means of preventing the disease, dentists during the past one hundred years or so have been endeavoring to preserve the teeth by filling the cavities as they appear and by restoring, to the best of their ability, the lost dental tissues by artificial substitutes. In every generation the dental profession has made some attempt to study the underlying causes of the disease and to discover some means of its prevention. During the past few years, however, scientific investigations of this problem have been greatly increased and well-organized research groups have been making intensive studies of the disease. As a result of these studies certain definite facts have been established and many preconceived ideas have been shown to be fallacious. Although the problem has not been fully solved, distinct progress has been made and a clearer understanding of the true nature of the disease has been attained. It is the purpose of this paper to state the outstanding achievements of recent researches on dental caries.

The disease in question is most unique. There is no other pathologic process which even remotely resembles it. Dental caries is not comparable to caries of the bone. It is not a true necrotic process, nor is it attended by inflammatory reactions in the affected tissues. It is characterized by the formation of progressive lesions in the teeth, simple decalcifications by acids formed locally as a result of the fermentation of carbohydrates by certain aciduric types of bacteria. The process is dependent on the infestation of the mouth by specific types of bacteria capable of producing acids by the fermentation of residual carbohydrate food materials in the mouth, and capable of living in their own acid products. These bacteria

belong to the lactobacillus group and to the general type which is commonly designated as *B. acidophilus.*

These organisms may be held in contact with the teeth over long periods of time, in which position they are virtually outside of the body proper. That is, they are at no time in immediate contact with the blood serum or the natural immunologic forces of the body and may be subjected to them only through the intermediary of the salivary or mucous gland secretions. The organisms of caries have no direct pathologic action on the tooth enamel, nor do they live at the expense of that substance. Rather do they produce their specific effects indirectly through the acids which they elaborate during fermentation. These organisms are non-pathogenic inhabitants of the oral cavity, which live at the expense of their immediate environment.

The unusual character of this process and its wide variance from other forms of bodily disease have made it extremely difficult to understand, and much valuable time and effort have been expended in the fruitless attempt to correlate it with other forms of degenerative diseases. In the olden days dental caries was considered to be a necrotic process resulting from inflammatory changes in the tooth itself. With the development of histologic studies it became evident that the dentine and enamel contain no circulatory systems capable of inflammatory reaction. Still, the old humoralistic idea remains even to-day, in the form of a belief by many that the activity of dental caries is largely controlled by the hardness and softness of the teeth. The fact that clinical and experimental evidence has clearly shown that the activity of the disease is not necessarily related to the perfection of tooth structure seems not to have been universally grasped or its significance realized, for we still hear the admonition "Feed your teeth" for the prevention of dental caries. The great majority of students in this field, however, have long since agreed that the determinant causative factors in dental caries are not resident in the tooth itself.

There are those who have looked to mouth cleanliness and hygiene as means of preventing this dental disease. Except when carried to an extreme and impractical degree these measures have failed to give any high degree of protection. Clinical observations clearly indicate that the activity and extent of dental caries may be quite unrelated to the degree of mouth cleanliness. Relatively clean teeth may be extremely carious and filthy mouths may be wholly free from defect. It has been difficult to harmonize these observations with the concept of dental caries as a bacterial disease until, by quantitative cultural measures, it was definitely shown that, as a rule, in caries-free mouths, irrespective of the state of mouth hygiene, *B. acidophilus* is either totally absent or is present in relatively small numbers. In those individuals in which caries is active there are usually high numerical counts of that organism. As in other forms of bacterial diseases, filth and infection may not be synonymous. The important consideration is not filth itself but the character of the bacterial flora which it habitually contains. Mouth hygiene, therefore, may influence the rate and extent of dental caries but in itself does not determine the occurrence of the disease. That function is exercised by the degree of infestation by *B. acidophilus,* irrespective of the degree of mouth cleanliness.

Contrary to the widely accepted view, *B. acidophilus,* the active causative agency in dental caries, does not inhabit all mouths alike. In some individuals the organism is totally absent and, when implanted therein repeatedly, does not grow but promptly disappears. In others it appears either intermittently or in very small numbers. In those individuals in which dental caries is active, as a rule, it grows luxuriantly and is constantly found on the teeth and in the saliva. In view, therefore, of this fact the next goal to be attained in the study of this problem is that of a fuller understanding of the exact mechanism by which the degree of activity of *B. acidophilus* in the mouth is controlled. That is, what are the conditions which inhibit its growth in one mouth and favor its active proliferation in another?

In the search for that important variable which determines the growth and degree of activity of the aciduric bacteria in the mouth, three general considerations appear to be most directly related to the process and might reasonably be expected to be significant. These are: First, the chemical constituents of the salivary and oral secretions; second, the possible immunologic principles of the saliva, and third, the character of the retained food debris remaining about the teeth. To these considerations others might be added which perhaps are more important but, at the present time, these are the most apparent factors directly related to the disease in question.

Proximate Factors in Dental Caries

I. *The Chemical Constituents of the Oral and Salivary Secretions:* Many phases of the chemical constituents of the saliva have been studied more or less intensively in the search for some characteristic chemical state which could be correlated with the activity of dental caries. At the present time the major interest is being centered upon the calcium, phosphorus and pH of the saliva, the opinion being held and frequently stated that these may act as controlling factors in dental caries. Furthermore, the feeding of calcium and phosphorus and alkaline-ash

foods has been recommended for the control of the disease.

During the past two years the University of Michigan dental caries research group has been engaged in a very intensive study of two well-selected groups of children, one of which was distinctly free from dental caries and the other extremely susceptible to it. The object of this study was to determine whether or not chemical differences existed between the saliva or the blood of caries-free as compared with caries-susceptible individuals. As the result of observations which were repeated on the same individuals at intervals of several months it was found that, although certain variations could be detected, there were no constant differences in the total calcium, total phosphorus or pH of the blood or the salivas of the two groups.

These investigations definitely indicate that, whatever controlling influence the saliva may have on dental caries it is not by virtue of its total calcium, total phosphorus or pH. Furthermore, in a correlated study of a small number of cases, no differences could be found in the total calcium, inorganic phosphorus, pH or the CO_2 combining power of the blood. These observations strongly negate the hypothesis that dental caries is the result of low calcium or low phosphorus content of either the blood or the saliva or is due to a condition of acidosis, statements which frequently have been made but are unsupported by adequate scientific evidence.

II. *Immunity against B. acidophilus:* Many attempts have been made to demonstrate some bactericidal agency in the saliva which might act as a controlling influence on oral sepsis, but as yet no such immunologic principle has been found. There are indications, however, that some form of bacterial control does exist for, as previously stated, *B. acidophilus* can not be induced to grow in many mouths in which that organism is consistently absent.

In a study of this question the Michigan group made extensive bacteriologic surveys of both the mouths and the intestinal tracts of caries-free and caries-susceptible individuals. They found that *B. acidophilus* was invariably present in the mouths and intestinal tracts of caries-susceptible individuals, but that it was absent or appeared intermittently in both the mouths and intestinal tracts of caries-free individuals. In view of the general impression that this organism is universally present in the intestinal tract we think it particularly significant that the only negative feces cultures were obtained in caries-free cases.

Certain observers (Boyd and Drain, Tucker and others) have been unable to demonstrate a constant relationship between oral *B. acidophilus* and dental caries and have questioned the significance of that organism as a specific etiologic factor in the disease. Bacteriologic studies in the field of dental caries are attended by certain difficulties, which may easily give rise to confusion and erroneous conclusions, especially to those who have no intimate knowledge of the disease under consideration. In making such bacteriologic surveys of the mouth it is most difficult and often impossible to determine whether, at any given time, dental caries is active or passive. Errors in such clinical assumptions will lead to erroneous conclusions. *B. acidophilus* may be present but not generally distributed throughout the mouth, even in cases of pronounced caries activity. It may be limited to certain definite areas of the teeth which are undergoing carious disintegration and be absent from other noncarious tooth surfaces. Consequently, diagnostic tooth scrapings which are not taken directly from actively carious areas may be negative. Conversely, in caries-immune or caries-arrested mouths qualitative cultures may be positive for *B. acidophilus* but if quantitative studies are made of such cases it will be found that these organisms are present in exceedingly low numbers and often are transitory in occurrence. Simple qualitative bacteriologic surveys of the mouth are therefore of doubtful value in the study of dental caries. The intensive bacteriologic and clinical studies of thousands of cases over a period of five years, which have been made by the University of Michigan group, leave no room for reasonable doubt as to the specificity of *B. acidophilus* as an active etiologic factor in dental caries. This view has been corroborated by the work of Rodriguez, Thompson and Enright.

In the search for some general immunologic principle which might control the growth of that organism in the mouth and the intestinal tract the Michigan group have studied selected groups of caries-free and caries-susceptible children, whom they inoculated intradermally with filtrates of *B. acidophilus*. It was found that the majority of caries-free subjects showed no reaction, but in many of the susceptibles there appeared localized areas of erythema, 10 to 30 mm in diameter within eight hours after inoculation. Repeated injections of the filtrate failed to desensitize the positive cases.

A polyvalent vaccine was prepared from forty strains of *B. acidophilus* and was administered to five cases which had given positive skin tests. In two of these, the skin tests became negative and agglutinins against *B. acidophilus* appeared in the blood. Unfortunately, this study has been hampered by the fact that in certain of these cases large sterile abscesses were formed at the site of inoculation which persisted for a considerable period of time. A new series of experiments are now under way in which autogenous vaccines will be used.

In the study of the blood sera of caries-free and caries-susceptible individuals it was found that in the former group *B. acidophilus* agglutinins occurred in dilutions as high as 1/640, while in the latter they were present in low dilutions or were absent. These studies are only in their infancy, but the findings thus far obtained strongly indicate the existence of some form of general immunologic principle which controls the growth and activity of *B. acidophilus* in the mouth and the intestinal tract.

III. *Retained Food Debris:* The character of the oral bacterial flora is profoundly influenced by the amount and character of food debris remaining in the mouth. If the residual foods are largely proteins, proteolytic types of organisms will likely predominate. If they are chiefly carbohydrates, overgrowths of fermentative bacteria are favored. It is upon the residual carbohydrate food debris that the aciduric bacteria of caries depend for their maximum growth and for the source of material for acid production. If the mouth could be kept continually free from carbohydrates *B. acidophilus* would be either absent or very low in activity and, in the absence of fermentable materials, would be wholly unable to produce dental caries. The amount and character of carbohydrate food debris in the mouth and about the teeth constitutes, therefore, a very important factor in this dental disease.

Constitutional Factors in Dental Caries

It is commonly observed that the occurrence and degree of activity of dental caries is definitely related to certain constitutional states of the individual. Of these, the more evident are inherited characteristics, age, bodily health and nutritional status. These constitutional states, through their influence on general metabolism, unquestionably affect the nature of the salivary secretions, their chemical constitution, physical properties and total amount. In this manner the constitutional status of the individual may influence the activity of the aciduric bacteria in the mouth and thus determine the progress of dental disease.

I. *Heredity:* The existence of an inherited tendency for or against dental caries is indicated by the fact that in civilized communities 90 to 95 per cent. of all children suffer from the disease, while 5 to 10 per cent. of individuals are not so affected. That is, a small percentage of people have some inherent quality that protects them from aciduric invasions of the mouth which the great majority of individuals do not possess. The tendency to or the freedom from this disease very definitely runs in families, having many of the characteristics of familial inheritance.

II. *Age:* Although dental caries is very prevalent during childhood and adolescence, after the age of twenty there is a marked decrease in its activity. Many who have been seriously affected during the early years of life have little or no decay of the teeth during middle age. It appears, then, that when the individual reaches early maturity the changing metabolic status produces conditions less favorable to the activity of aciduric bacteria in the mouth and dental caries.

III. *Bodily Health:* It is commonly observed that severe illnesses and metabolic disturbances of various types may be followed by a marked activity of dental caries. A classic example of this is the increase of dental disease which so frequently follows pregnancy and childbirth. The metabolic disturbances associated with these general physical states undoubtedly influence oral conditions and dental health.

IV. *Diet and Nutrition:* Perhaps the most notable recent contribution to the study of dental caries has been the accumulation of evidence pointing to foods and nutritive functions as factors of major importance in the disease. This knowledge has come largely through three general fields of inquiry, namely, racial studies, animal experimentation and human dietary experiments.

A. *Racial Conditions:* It is a well-known fact that dental caries is distinctly a disease of modern civilization. The natives of Alaska, Newfoundland, South America, the South Sea Islands, Africa, interior Europe and Asia who live segregated lives quite remote and untouched by modern civilization are almost wholly free from dental caries. When these people adopt civilized life or move into civilized communities their children become highly susceptible to dental disease. In a study of the essential differences between uncivilized and civilized life which might be related to the prevalence of dental caries the most outstanding characteristic is that of diet. As long as primitive man lives on the simple foods which are indigenous to his locality, he has little need for a dentist, but when he adopts the white flour, sugar and canned goods of civilized life he and his children invariably are stricken by dental disease which is often more severe than among civilized communities.

B. *Animal Experimentation:* In many of the early studies of diet and nutrition which were made on animals it was observed that, with the feeding of certain deficient diets, caries-like lesions appeared in the teeth. Since that time extensive animal experimentations have been carried on to determine what form of dietary deficiency is most important in the production of dental caries. Certain observers have stated that vitamin C is most important, others that calcium, phosphorus and vitamin D are more significant, and still others believe that the acid-base balance is a determining factor. In all the animal experimenta-

tion so far reported there is found no conclusive evidence in support of any of these views. The original statement of McCollum and Grieves—that the percentages of caries developing under the various diets are interesting but they do not point definitely to any one characteristic of diet as being more significant than another in its relation to dental caries—has not been controverted.

C. *Human Experimentation:* During the past few years a number of caries research projects have been carried on in which practical application of the several dietary theories regarding this disease have been actually tried on groups of children under observation. The observations made in these experimentations and the published data are extremely valuable contributions to the study, notwithstanding the fact that there is considerable difference of opinion as to the interpretation of the findings. Perhaps the most notable of these are the dietary studies of May Mellanby, Boyd and Drain, H. F. Hawkins, Milton T. Hanke, Sherman L. Davis and the University of Michigan group. In some of the dietary programs which were employed in these studies certain food factors were accentuated as being most important dietary deficiencies and any beneficial effects which were observed were attributed to the fortification of these elements. Mellanby and Davis stressed the feeding of calcium and vitamin D, Hanke fed large quantities of vitamin C bearing foods, and Hawkins emphasized the calcium and alkaline-ash intake, while Boyd and Drain and the Michigan group studied the effect of adequate, well-balanced diets on dental health. It is interesting to note that all these observers report an appreciable decrease in the activity of dental caries as a result of the particular dietary method which they used. In some instances it amounted to almost a complete control of the disease during the period of observation. Those who accentuated calcium and phosphorus, vitamin D and C or the alkaline-ash content point to the improvement of dental conditions in the cases which they fed as a proof of the importance of these food elements. It must be remembered, however, that not one of these projects was an adequately controlled experiment. In every instance in which a single element was increased other food principles were also included which may have been equally important protective principles, with the possible exception of certain experiments of Mrs. Mellanby. There is, therefore, no conclusive evidence to be found in the dietary experimentations thus far reported to warrant the assumption that any one food factor is more important than another in its relation to dental caries.

In an analysis of these dietary experimentations there is a certain trend or common denominator which runs through them all; namely, that all the dietary programs, irrespective of the particular view-point stressed, provided fairly adequate and well-balanced rations. A notable exception to this principle has been found by the Michigan group in a colony of three hundred children who are receiving an inadequate diet but have exceptionally fine dental conditions, low *B. acidophilus* counts and little or no dental caries. These children, who have been observed over a period of four years, are residents of an orphanage. Their diet has been practically uniform during this period and has been considerably below the standard nutritional requirements in calcium, phosphorus, vitamins D and C and caloric values. One other food factor existed which may be significant. The sugar intake was reduced to the lowest possible minimum. The children received little or no candy, no sugar in beverages or on cereals and no highly sweetened cakes or preserves. The desserts were limited to raw apples. Whether or not the exceptionally fine dental conditions and the freedom from dental caries which prevailed throughout this period of observation can be attributed to some particular dietary principle or to the low consumption of sugar can not be definitely stated at this time.

Further studies of the effect of various types of adequate diets and the feeding of different forms of sugar on dental caries are being made by the Michigan group on children in the University Hospital under the direction of Martha Koehne.

SUMMARY

The chief consideration in a study of this kind is obviously the prevention of the disease in question. Effective preventive measures, however, must be based upon a full knowledge of the factors involved in the production of the disease. Unfortunately, at the present time there are certain missing links in the evidence concerning the etiology of dental caries which prevent a clear statement of facts in their entirety. Because of our present lack of knowledge as to certain details, the measures employed for the practical control of the disease are necessarily of the trial and error method in which there are many opportunities for misapprehension and erroneous conclusion. The rationale of any preventive procedure may only be evaluated by a clear knowledge of the established facts and a correlation of the unknown with the known.

Certain of the more important facts which should be borne in mind in the evaluation of new theories or experimental evidence may be stated as follows:

(1) Dental caries is a bacterial disease of the oral cavity which is characterized by acid fermentations and a decalcification of the teeth.

(2) The occurrence of dental caries is not determined by the structural quality of the tooth nor by the degree of cleanliness of the mouth.

(3) Dental caries is definitely favored by certain phases of civilized life.

(4) Dental caries is related to certain constitutional states of the individual, such as inherited characteristics, age and bodily health.

(5) A small percentage of people are hereditarily immune to *B. acidophilus* and by the inhibition of the growth of this organism in the mouth are thereby protected from dental caries, irrespective of all other considerations.

To this list may also be added the fact that certain dietary programs appear to be inhibitive of dental caries. The manner in which diet exerts a controlling influence on the disease; whether it is through the determination of the character of the local food residues in the mouth or through the production of metabolic states which determine the activity of the aciduric organisms in the mouth is not known. Nor, indeed, has it been determined precisely what types of diets are most beneficial in this regard.

At the present time the greatest promise for the ultimate solution of the problem seems to lie in the study of the chemistry of the saliva and its immunologic reactions against the organism of dental caries, and in a further study of diet in its relation to dental disease. To this end it is highly desirable that group studies be made in which the allied sciences, chemistry, nutrition, bacteriology and dentistry may be correlated in a truly scientific attack on this very difficult and important problem in human welfare. It is only by studies of this broad nature that any adequate concept of the nature of this disease or the means of its prevention may be attained.

THE ENGINEERING FOUNDATION

By ALFRED D. FLINN
DIRECTOR

Objectives and Policies

THERE are basic laws of nature in the field of ethics that are as certain in operation as the natural laws in the field of physics. Engineers are as vitally concerned with economics, which lies partly in each of the fields of ethics, engineering and finance, as with mechanics, in the field of physics.

The Engineering Foundation devotes its resources, therefore, to human as well as technical aspects of engineering problems of wide interest. It promotes research and other activities having as main objectives "the furtherance of research in science and engineering and the advancement in any other manner of the Profession of Engineering and the good of mankind," in the language of its deed of gift.

The foundation's aid to the advancement of the profession extends to activities aimed at better understanding and application of natural laws fundamental to both physics and ethics. Hitherto emphasis has been on technical research, although humanic subjects have received attention, too. Such appeared to be the preponderance of need in our country's development until recent years—or rather that was the need of which engineers and industrialists were most conscious. Within a few years the consciousness of need has shifted, and consequently the emphasis in the foundation's program may advisedly be shifted correspondingly.

Leadership, cooperation and effectiveness are keynotes in the foundation's policies. They are personal traits of its founder, Ambrose Swasey, of Cleveland, Ohio.

Organization and Administration

The founder is one of the surviving organizers of The American Society of Mechanical Engineers. For several years he considered how best to make a gift to assist his fellow engineers, through his own society or some other organization, in working out problems for which no means had then been provided. After consulting friends competent to advise, he anonymously proffered a gift in May, 1914, to the United Engineering Society, now known as United Engineering Trustees, Inc. This corporation was created in 1904 under a special act of the New York legislature by the three national societies of mining, mechanical and electrical engineers to hold and administer for them jointly real estate and funds, "to advance the engineering arts and sciences in all their branches, and to maintain a free public engineering library." The American Society of Civil Engineers became a member of this group in 1916. Since the tenth of August of that year there have been four founder societies.

Mr. Swasey's conception was unique. He committed his gift not to a self-perpetuating board, but to a group of national engineering societies. He avoided the inclusion of any personal name in the name of the foundation. He did not wait until the end of his life. He gave while he could enjoy the satisfaction of seeing his money at work. He added to his first

gift others in 1918, 1920 and 1931, bringing his total to three quarters of a million dollars. He intended his gifts to be the nucleus of a large endowment, to which many other persons would contribute as years passed.

By the terms of the deeds or letters of all gifts for endowment the principal is committed to United Engineering Trustees, Inc., for safe keeping and administration, but the net incomes of the funds created by the gifts are controlled and administered by the foundation board. The board of trustees has twelve members, three appointed by each of the so-called founder societies, namely, American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers and American Institute of Electrical Engineers, having together a membership of more than 60,000. The foundation board has sixteen members, of whom thirteen are representatives of the societies named and three are members-at-large. Members of the foundation board and the trustees are appointed for terms of three years with eligibility for reelection. The legal status of the foundation board is that of a committee or department of the corporation, United Engineering Trustees, Inc. Contributions of money, services or materials for current use may be made to The Engineering Foundation directly. The foundation board has discretionary power in the disposition of moneys and other contributions received by it from the board of trustees or from other sources.

The Engineering Foundation provides for combining the gifts of many persons under one management, for common or diverse purposes, in perpetuity or for limited periods, as may be stipulated by donors. Thus it is a "community trust" for a community delimited by common interests, those of the profession of engineering, instead of geographical boundaries. In the form of organization of the foundation hence inheres the following advantages: Conservation of resources by continuity of service of experienced trustees and advisers; prevention of such obsolescence of funds as has often occurred through attempts of donors to foresee far ahead in an evolving world; avoidance of restraint of action of future generations; advantages of doing things on a larger scale; wisdom in use of resources through advice of the well-informed; continuance of activities under unified direction to useful ends; breadth of purpose and of benefit.

Resources

The foundation's endowment has increased from $200,000 in 1915 to $880,000 in 1933 and the income thus provided from $5,000 to $40,000, the total for 18 years being $459,000. Expenditures from this income totaled $449,600, and $187,000 in money contributed for current activities passed through its treasury. In addition, contributions of money, services and materials were made by organizations and individuals cooperating in activities which the foundation aided. Of these contributions no accounting was feasible, but they have been roughly estimated as having a value of $2,000,000. The total money measurement of the cost of activities in which the foundation participated may thus be put at more than two and a half million dollars. But money units can not measure the true value of the benefits to the community of even those projects in which substantial sums were involved, and much less of the innumerable incidental services in which the expenditures were negligible.

For administration of endowment the cost per annum has averaged less than 0.2 per cent. of the principal, or 3.6 per cent. of the gross income, in recent years, including investment advice, custody of securities, accounting and audits by certified public accountants annually. The foundation's funds are exempt from New York and federal taxation. Contributions to the foundation are deductible from the contributor's total income for the year in computation of federal and some state income taxes, up to 15 per cent. of the contributor's net income.

Legacies totaling approximately a half million dollars are definitely known to be destined for the foundation in due course.

Besides money, the resources of the foundation comprise the special abilities of members of engineering societies and their willingness to serve on committees and as advisers; the organizations and the union of its founder societies; the good-will of other technical societies and of scientific associations; the cooperation of many universities, of other institutions and of governmental bureaus; the financial and other support of numerous industrial companies and of some trade associations; and its own accumulating experience.

Examples of Activities

What the foundation has been doing, as an instrumentality of its founder societies, since the first meeting of its board in April, 1915, in addition to developing plans and policies in a unique sphere of activity, can be shown by examples of "work done."

World war developments in their early stages brought to American scientists and engineers a realization of the importance of the advancement and application of all the sciences. The National Academy of Sciences took steps at its spring meeting in 1916 toward organizing for services to our country in war and in peace a body whose membership should embrace representatives of many sciences and arts. National engineering societies promptly cooperated in creating the National Research Council. Money was lacking with which to begin action. The Engineering

Foundation met this emergency and thus assured the establishment of the council. This was the foundation's first notable undertaking. It has continued to the present time its relationships with the council. Articles in the issues of SCIENCE for April 14, May 26, June 9 and 30, July 14, August 4 and 25 and September 8, 1933, have informed its readers comprehensively on the National Research Council. These articles supply a basis for estimating the value of this first undertaking.

The founder societies in 1919 cooperated with the National Research Council in establishing its division of engineering in the after-war reorganization. Some members of this division always are also members of the foundation board. The foundation has provided offices for the division in Engineering Societies Building, New York, since May 1, 1919, and has cooperated with the council in a number of research projects, including organization of Advisory Board on Highway Research, American Bureau of Welding and Personnel Research Federation; fatigue (endurance) of metals, marine piling, molding sands for foundries, pulverizing of ores, cements and fuels, heat transfer and electrical insulation; also compiling a directory of research laboratories in the industries of the United States.

For spreading understanding and appreciation of science, invention, engineering and their applications the foundation published *Research Narratives* from January, 1921, to December, 1932. These tiny leaflets contained very short stories of interesting achievements, contributed by eminent scientists, inventors and engineers from their personal experiences.

Betterment of engineering education has been promoted through assistance to the Society for the Promotion of Engineering Education in investigations of institutions, methods and needs, and its summer schools for engineering teachers. Through the education research committee, representing six national engineering societies and the foundation, there was produced in November, 1932, a booklet entitled "Engineering: a Career—a Culture, a Message to Young Men, to Parents and Teachers." It is spreading all over the country and has received encouraging endorsement for its practical usefulness.

An adventure in adult education January to June, 1933, achieved a good measure of success. Ten "Courses for Disengaged Engineers" were given without charge in Engineering Societies Building on technical, financial and personnel subjects, under the auspices of the foundation, as a part of the services of its founder societies to their members and other engineers suffering from the business depression. Columbia and New York Universities, the Polytechnic Institute of Brooklyn, the Stevens Institute of Technology, the College of the City of New York, the Personnel Research Federation, a committee of the disengaged engineers, numerous companies and many individuals provided the instruction, administration and other services gratuitously. Incidental expenses were provided by the professional engineers' committee on unemployment and private subscriptions. Leaders in industry, engineering and education gave their public endorsement.

More than 600 engineers registered in the classes. Attendance was well sustained. Both students and teachers declared that these courses constituted one of the most useful aids rendered to engineers without employment, particularly in sustaining their morale and broadening their views of life and the profession.

To economic problems the foundation has at various times devoted some attention, but has as yet not participated extensively in any project.

To many technical researches of its founder societies it has given financial and other assistance. In the field of civil engineering a ten-year investigation of arch dams has just been terminated; a study of concrete arches and another of steel columns, for bridges and buildings, are nearing completion, and a fundamental and technical research in earths and foundations is progressing in this and other countries, yielding many practical benefits as it goes forward.

In mining and metallurgical engineering a collation of information on mining methods and a basic research in iron blast furnace slags produced results useful to engineers and industries; a novel experimental study of mining and strata problems, utilizing specially designed centrifuges, is progressing encouragingly, and the alloys of iron research is critically reviewing the world literature in many languages, making carefully selected information readily accessible with great economy of time and effort of industrial, scientific and engineering workers, and pointing out gaps that need laboratory research on alloy steels and irons.

Among mechanical engineering researches may be mentioned properties of steam, lubrication of machinery, strength of gears, use and care of wire ropes in elevators, construction operations and mining, effects of temperature on the properties of metals and the cutting of metals in manufacturing operations.

The electrical industry is so closely related to its basic sciences and has so many notable laboratories that there are relatively few problems for which the American Institute of Electrical Engineers seeks aid from the foundation. In insulation there have been researches in the fundamentals of dielectrics, and in electric welding, basic researches on pure iron electrodes and on nitrogen in welds.

Increase among engineers and manufacturers of

understanding of the possibilities and benefits of real research has been a result of great value from these society research activities, in addition to the specific technical knowledge gained.

RESEARCH INCIDENTS

For the arch dam investigation an experimental dam 60 feet high was built on Stevenson Creek, a feeder of the San Joaquin River, in a wild gorge of the Sierra about 60 miles from Fresno, California. This dam was elaborately equipped with instruments and subjected to many tests. Several floods sent water over its top to a depth up to three feet or more and partially filled the little reservoir with boulders and sand. Nevertheless, although only two feet thick for most of its height, this dam built in 1926 survives without serious injury. Tests of tiny celluloid models at Princeton University and of a large mortar model at the University of Colorado, made independently, gave results in almost exact agreement with the tests of the dam. Models of dams built by the Bureau of Reclamation also were made and tested. A number of large dams built for water supplies of cities, for irrigation or for power development were tested with special instruments. These dams were of extremely various types, including one composed of three domes and others of arches ranging from very small top thickness to thickness wide enough to carry a highway. The many difficulties in testing large dams in service and the excellent results from tests of models demonstrated the dependability as well as the great economy to be realized from intelligent, skilful use of models.

In studying concrete and reinforced arches some small and some very large models were built and tested to destruction in laboratories. Extensive observations were made also on some large highway bridges. Among them was a bridge of several spans on a highway within a reservoir site, which would have to be abandoned. This bridge was subjected to a number of tests to limits that could not have been allowed on bridges in service, and, having withstood them all, finally was destroyed by bombing attack from the air. All these tests, including the final destruction, were carefully recorded and studied. Ohio State University, University of Illinois and the U. S. Bureau of Public Roads collaborated in this research.

In the investigation of arch dams and concrete bridges the plastic flow or deformation of concrete was noted in some instances. This phase of the behavior of concrete became the subject of extensive experimental research at the University of California and in other places.

Pure iron electrode experiments led to discoveries of new phenomena in electric arcs, at Lehigh University.

The use of a specially designed centrifuge and auxiliary apparatus is demonstrating that problems involving phenomena of rock strata and masses of earth can be studied in a laboratory and results obtained that correspond with the occurrences in nature. This has been a field which many thought defied all possible endeavors for laboratory study. This research is being conducted at the School of Mines, Columbia University.

COLLABORATION

Certain general investigations can best be undertaken by the engineering societies and The Engineering Foundation, or organized by them on cooperative plans. A single company, for self-evident reasons, will rarely undertake projects of this kind. Many such projects are beyond the possibilities of private organizations. Some are outside the fields of governmental bureaus or would suffer delays beyond the control of bureau heads. Always there will be work to be done by an impartial institution of professional engineers.

In most projects in which the foundation has participated active collaboration or financial assistance was contributed by engineering societies, universities, governmental bureaus, research institutions, industrial corporations, trade associations, bankers and individuals, including a few in other countries. In numerous instances the foundation's efforts and money constituted the starter needed for preliminary exploring, organizing and financing. Other undertakings the foundation has assisted in critical periods.

The foundation aids researches and other enterprises in a variety of ways, but in the main refrains from direct management. It has no laboratories nor staff nor other facilities for conduct of research. Cooperatively, however, all needed facilities for projects in which the foundation has participated have been made available.

Activities of the foundation have direct connection with human life. Knowledge gained flows through four channels: the engineering colleges, by teaching and reports of research; the profession, by practise; industries, public utilities and public works, by supply of community needs; and the engineering societies, by meetings and publications.

The term "Engineering Foundation" stands for four concepts: First, a body of representatives of its founder societies, associated for the purposes of fostering research and the application of the sciences through engineering, and the performing of other functions under its deed of gift, "for the good of man-

kind"; second, an endowment fund owned by United Engineering Trustees, Inc., as trustee for the founder societies; third, a department of United Engineering Trustees, Inc., based on the intellectual and physical resources of the engineering societies, comprising men, means, activities and good-will; fourth, an integral part of the united organism of its founder societies.

OBITUARY

DR. E. N. LOWE

DR. EPHRAIM NOBLE LOWE was born near Utica, Mississippi, in 1864, the son of a physician and planter. He received the degree of bachelor of philosophy from the University of Mississippi in 1884, and the degree of doctor of medicine from Tulane University in 1892.

He practised medicine and did geological and biological work for some years in Colorado and other parts of the Middle West, where among the mountains, the plains and the streams he deepened that love for nature already acquired in his native state.

Returning to Mississippi, he continued the study of geology and natural history and soon became connected with those departments in the university, spending several summers in the meantime in study at the University of Chicago.

He was made state geologist in 1909 and head of the department of geology in the University of Mississippi in 1924, and continued to hold both these positions till his death on September 12, 1933. He was laid to rest two days later among his native hills and in sight of the stately home where he was born.

Dr. Lowe published many bulletins on the geology of Mississippi, the last of which came from the press in the present year. He published also an important volume on the botany of the state, called "Plants of Mississippi" (1921), especially valuable because it is a pioneer work in that field.

Dr. Lowe may be called the last of that fine school of naturalist-geologists of this section, which was represented by Dr. Eugene W. Hilgard ("Geology and Agriculture of Mississippi," 1860), Dr. James M. Safford ("Geology of Tennessee," 1869), and Dr. Eugene A. Smith, whose many reports on the geology of Alabama are well known. The author of this appreciation did not know Dr. Hilgard personally, but he counts it among his priceless memories to have been thrown closely as a student with Dr. Safford and to have known and loved Dr. Smith and Dr. Lowe in his later years—all most enthusiastic scientists, most loyal friends and most lovable of nature's noblemen.

In the death of Dr. Lowe the state has lost a painstaking scientific investigator, the university an able professor and society an excellent member.

Dr. Lowe was a fine example of sweet reasonableness in all things. His was a beautiful character. He was gentle and charitable, yet true to his ideals and absolutely fearless. He was a patient and careful student of nature, an inspiring teacher, a loyal friend and a delightful companion. In him there was no ostentation and no offense. He loved the fields and the woods, the birds and the beasts and the flowers; all nature was to him a book wherein to read, and his enthusiasm was an inspiration to others.

CALVIN S. BROWN

MEMORIALS

THE centenary anniversary of the birth of Cyrus Fogg Brackett, for thirty-five years professor of physics at Princeton University, was celebrated on October 24 at a meeting of the Princeton School of Engineering, attended by former students of Dr. Brackett. The principal address was made by Dr. Howard McClenahan, secretary of the Franklin Institute, Philadelphia, and director of the museum and Benjamin Franklin Memorial.

THERE was dedicated in Paris on October 11 a monument erected in memory of Charles Mourea, professor of chemistry at the Collège de France. M. Mourea was for twenty years editor of *la Revue scientifique*.

A BUST of Fritz Pregl, professor of medical chemistry and Nobel laureate, who died in 1931, has been placed in the hall of the University of Graz.

THE three hundredth anniversary of the birth of Anthony van Leeuwenhoek was recently celebrated at Delft. Addresses were delivered by Professor Gutterink, rector of the senate; Professor D'Arcy Wentworth Thompson, delegate from the Royal Society; Professor J. van der Hoeve, president of the Leeuwenhoek national committee. A wreath was laid on the grave of the scientist in the old church at Delft.

ACCORDING to *Nature*, a memorial to Sir Charles Parsons, who died on January 12, 1931, has been unveiled at the works of Messrs. C. A. Parsons and Company, Limited, at Newcastle-on-Tyne by his daughter, Miss Rachel Parsons. The memorial is formed of a medallion portrait of Sir Charles, in profile, carved in Bianca del Mara stone; this is surmounted by the family coat of arms. At the ceremony Miss Parsons said that the memorial was erected on the site of the room in which her father spent so many hours of his

life working at the scientific and engineering investigations which appealed to him above everything else. The memorial was designed by Mr. Maurice E. Webb, and Mr. Reid Dick was the sculptor.

THE *Journal* of the American Medical Association reports that in order to perpetuate the memory of Professor Fernand Widal, who died in 1929, former pupils have had erected a bust by the sculptor Landowsky in the clinic at the Cochin Hospital, Paris, where he gave the major part of his instruction and carried on his researches. Under the bust are engraved the titles of his principal works: "serodiagnosis, cytodiagnosis, pathogenesis of edemas, azotemia, classification of nephritis, colloidoclasia." Imposing ceremonies were held at the dedication, presided over by the minister of public health. Addresses were delivered by Professor Achard and Professor Bezançon, collaborators of Widal; Professor Lemierre, his most eminent pupil, and Dr. Mourier, director of the Assistance publique in Paris.

RECENT DEATHS

DR. OLIVER CUMMINGS FARRINGTON, curator of geology at the Field Museum of Natural History since 1894, died on November 2. He was sixty-nine years old.

WILLIAM THOMAS LYLE, of Washington and Lee University, died on October 31. He was head of the department of civil engineering and was known as an authority on city and park planning. He was fifty-eight years old.

ANDREW SHERWOOD, formerly assistant state geologist of Pennsylvania, died in Oregon on October 31, at the age of eighty-five years.

DONALD JOHN ARMOUR, surgeon to the National Hospital for Nervous Diseases, and Consulting Surgeon to the West London Hospital, died suddenly on October 23 at the age of sixty-four years, while present at a council meeting of the Medical Society of London, of which body he was treasurer.

PROFESSOR LEONARD JAMES ROGERS, F.R.S., late professor of mathematics in the University of Leeds, died on September 12 at the age of seventy-one years.

DR. PIERRE PAUL EMILE ROUX, since 1904 director of the Pasteur Institute, Paris, died on November 3, at the age of seventy-nine years.

SCIENTIFIC EVENTS

SIR HENRY LYONS AND THE SCIENCE MUSEUM

A PRESENTATION was made to Colonel Sir Henry Lyons, F.R.S., on October 11, on his retirement from the directorship of the Science Museum, South Kensington, by Lord Irwin, president of the board of education, on behalf of the Advisory Council of the Museum, under the chairmanship of Sir Richard Glazebrook, F.R.S.

According to an account given in the London *Times*, an illuminated address, signed by all the members of the council, read as follows:

Dear Sir Henry—We, your friends, members of the Advisory Council of the Science Museum, wish to express to you, on the occasion of your retirement after holding for 13 years the position of director of the museum, our great regret at the termination of your services and our warm appreciation and admiration of the work which you have done.

In 1920, when you were appointed, the museum was a small institution known only to a few. The eastern block, planned in pre-war days by Sir Hugh Bell's Committee, was incomplete. The collections, scattered throughout various unsuitable buildings, were without order and arrangement. You had the vision to realize the position the museum might take and the value it might be to science and to industry. By your tact, energy and ability you have made it what it now is and is known to be—a treasure-house of past achievements and an inspiring guide to future progress. One single fact suffices to indicate the magnitude and success of your work: the number of visitors has increased from about 400,000 in 1921 to nearly 1,250,000 in 1932.

We claim for the museum a foremost place among institutions of its kind, and recognize that it is to you that this is due. You lay down that work with every good wish from all of us for your future happiness and prosperity.

The presentation of the address, together with a writing desk as a gift from the council, was made by the president of the board of education, Lord Irwin, who expressed his interest in the periodic exhibitions held in the museum, which served the double purpose of showing modern scientific developments and of illustrating their applications to industry. Sir Henry Lyons had, he said, done much for children, particularly in initiating the Children's Gallery, which now appeared so simple and straightforward. The number of visitors to the museum was a matter of which Sir Henry might justifiably be proud.

In his reply Sir Henry Lyons expressed his gratitude for a most enjoyable period of service. Sir Richard Glazebrook had had a long association with the museum since the departmental committee of 1910. The board of education had given an opportunity to try out the experiment of a modern technical museum. Only two such museums were yet in ex-

istence, but about a dozen others were in process of formation, closely modeled on the Science Museum. The expansion of science, technology and industry gave the museum an overwhelming variety of material to make intelligible and attractive. To vary it the museum obtained about 1,000 new exhibits each year and discarded some 800 of the old specimens. On October 4, it had had its millionth visitor this year, while five years ago its millionth visitor had walked in only on December 30. In replying to a question from the Brooklyn Child Museum as to what curriculum was used in the Children's Gallery, he had been able to say, "None, thank God; the children are allowed to wander as they will."

THE ANNUAL ELECTION OF OFFICERS OF THE AMERICAN CHEMICAL SOCIETY

NOMINATIONS for the office of president-elect of the American Chemical Society have been made by the local sections of the society. We take from *Industrial and Engineering Chemistry* the list of candidates with particulars in regard to their work:

ROGER ADAMS. Professor and since 1926 head of the Department of Chemistry, University of Illinois. A graduate, including Ph.D. degree, of Harvard University, and a student at the University of Berlin and the Kaiser Wilhelm Institute. Before going to the University of Illinois he was instructor in organic chemistry at Harvard. During the war he was major in the Chemical Warfare Service. He was Nichols Medalist in 1927, chairman of Section C, American Association for the Advancement of Science, in 1927, has served as associate editor of the *Journal of the American Chemical Society*, as chairman of his local section, Councilor, Councilor-at-Large, and now Director of the American Chemical Society. He is a member of the National Academy of Sciences, fellow of the American Academy of Arts and Sciences and of the National Research Council, and member of the Deutsche Chemische Gesellschaft and a number of fraternities.

ROSS AIKEN GORTNER. Professor of agricultural biochemistry and chief of the Division of Agricultural Biochemistry, College of Agriculture, University of Minnesota, and the Minnesota Agricultural Experiment Station. He is a graduate of Nebraska Wesleyan University, received his master's degree at the University of Toronto, and was a university fellow in chemistry at Columbia University, where he took his Ph.D. degree in 1909. He is particularly well known for his researches in agricultural, biological and colloidal chemistry, having been connected with the University of Nebraska, University of Toronto, the Carnegie Institution of Washington Cold Spring Harbor Laboratories and the University of Minnesota. He has been a member of various divisions and important committees of the National Research Council, has served as associate editor of the *Journal of the American Chemical Society* and the *Journal of Physical Chemistry*, and as assistant editor of *Chemical Abstracts*. He is American representative on the International Committee on Biochemical Nomenclature of the International Union of Chemistry. He has served as Councilor and Councilor-at-Large of the American Chemical Society, has been division secretary and chairman, president of the American Society of Naturalists, and is a member of a number of scientific organizations and of fraternities. He has written extensively on topics pertaining to biochemistry.

SAMUEL COLVILLE LIND. Director, School of Chemistry, University of Minnesota, since 1926. He is editor of the *Journal of Physical Chemistry*. Widely known for his work in radioactivity. He is a graduate of Washington and Lee University and the Massachusetts Institute of Technology. He obtained his doctorate at the University of Leipzig. He also studied at the University of Paris and the Institute for Radium Research in Vienna. He has taught at the Massachusetts Institute of Technology and the University of Michigan. He has been physical chemist and chief chemist of the U. S. Bureau of Mines, as well as associate director of the Fixed Nitrogen Research Laboratory. He served on the Radium Standards Commission, has been president of the Electrochemical Society, is a member of the National Academy of Sciences and other scientific organizations. He has been a member of the board of editors of Scientific Monographs and of *Chemical Reviews* and Councilor-at-Large of the society. Besides contributing to the scientific literature, he is the inventor of an interchangeable electroscope for radium measurements and originated the ionization theory of the chemical effects of radium rays.

HUGH STOTT TAYLOR. Chairman and David B. Jones professor of chemistry, Princeton University. A graduate, including advanced degrees, from the University of Liverpool, and a student at the Nobel Institute of Stockholm and the Technische Hochschule of Hannover. He has been connected with Princeton University since 1914. He has served on important committees of the National Research Council, saw service with the British Munitions Invention Department during the war, and is a fellow of the Royal Society of London. Nichols Medalist in 1928, was chairman of the Central Petroleum Committee of the National Research Council from 1926 to 1931, is a member of a number of scientific societies, including the Electrochemical Society, of which he was vice-president in 1930, the American Philosophical Society, the Faraday Society and numerous fraternities. His research has been in the field of physical chemistry. Among his contributions to chemical literature is the American Chemical Society monograph on "Industrial Hydrogen."

The membership have been asked to nominate Councilors-at-Large from the following list of members:

A. F. Benton, acting chairman, Chemical Faculty, University of Virginia.

William Lloyd Evans, chairman, department of chemistry, the Ohio State University.

F. C. Frary, director of research, Aluminum Company of America.

N. H. Furman, associate professor of chemistry, Princeton University.

Henry Gilman, professor of chemistry, the Iowa State College.

H. T. Herrick, principal chemist in charge, color and farm waste division, Bureau of Chemistry and Soils, U. S. Department of Agriculture.

A. E. Hill, professor of chemistry, New York University.

E. C. Kendall, professor of biochemistry and head, section of chemistry, Mayo Foundation.

Victor K. LaMer, associate professor of chemistry, Columbia University.

J. W. McBain, professor of chemistry, Stanford University.

John H. Nair, assistant director, Research Laboratory, The Borden Company.

H. A. Shonle, research chemist, Eli Lilly and Company.

Alexander Silverman, head, department of chemistry, University of Pittsburgh.

C. M. A. Stine, vice-president, member of the executive committee, and director, E. I. du Pont de Nemours and Company.

H. C. Urey, associate professor of chemistry, Columbia University.

E. H. Volwiler, vice-president in charge of research, Abbott Laboratories.

Harry B. Weiser, dean, Rice Institute.

THE AMERICAN INSTITUTE

THE American Institute will hold from November 8 to January 24 a number of technical round tables for members interested in discussing purely scientific subjects in addition to round tables of more popular interest. The subjects, followed by the names of the leader in charge and of the guest speaker, are as follows:

November 8. "Recent Studies of Apes" (Popular): Walter L. Hinman, Friends Seminary; Dr. J. H. McGregor, professor of zoology, Columbia University.

November 14. "Synthetic Resins" (Technical): Dr. Charles R. Downs, chemical engineer; Dr. George Barsky, consulting chemical engineer.

November 21. "Mental Disorders and Human Inefficiency" (Popular): Dr. A. A. Brill, psychiatrist; Dr. Harry Stack Sullivan, psychiatrist.

November 24. "Some Problems of Behavior as Influenced by Calcium Utilization" (Popular): Dr. James M. Brown, medical director, Reed and Carnrick; Dr. Walter Timme, professor of clinical neurology, Columbia University.

December 12. "Geometry and Physics" (Technical): Dr. H. H. Sheldon, chairman, department of physics, New York University; Dr. Edward Kasner, professor of mathematics, Columbia University.

December 14. "Isotopes of Hydrogen" (Popular): Dr. Victor K. LaMer, associate professor of chemistry, Columbia University; Dr. H. C. Urey, associate professor of chemistry, Columbia University.

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January 5. "Perfumes" (Popular): Colonel Marston T. Bogert, professor of organic chemistry, Columbia University; to be announced.

January 9. "The Farm as a Source of Industrial Raw Material" (Popular): Dr. Charles R. Downs, chemical engineer; Dr. William J. Hale, chemical director, Dow Chemical Company.

January 16. "Filterable Viruses" (Technical): Dr. L. O. Kunkel, department of plant pathology, Rockefeller Institute, Princeton; Dr. Thomas Milton Rivers, member of Rockefeller Institute for Medical Research.

January 24. "Recent Scientific Developments in Music" (Popular): C. O. Fairchild, physicist, Tagliabue Manufacturing Company; to be announced.

THE VIRGINIA ACADEMY OF SCIENCE

AT the recent meeting of the Research Committee of the Virginia Academy of Science, grants in aid of scientific research were made to the following:

Dr. W. E. Bullington, professor of biology, Randolph-Macon College, "'Spiraling' in Certain Lower Organisms."

Dr. Wm. R. Cornthwaite, professor of chemistry, University of Richmond, "A Synthetic Substitute for Insulin."

Mrs. Madeline Foreman, assistant professor of biology, Hampton Institute, "The Algae of the Dismal Swamp."

Dr. L. C. Morley, agent of the U. S. Bureau of Biological Survey, Richmond, "Infectious Enteritis in Quail."

Dr. Philip C. Scherer, associate professor of physical chemistry, Virginia Polytechnic Institute, "The 'Ripening' Process in Viscose."

Dr. D. C. Smith, associate professor of dermatology and syphilology, University of Virginia, "The Etiology of Psoriasis."

Dr. Carl C. Speidel, professor of anatomy, University of Virginia, "The Study of Living Nerves."

Dr. Edward Steidtmann, professor of geology, Virginia Military Institute, "Stream Travertine Deposits near Lexington, Virginia."

Dr. John H. Yoe, professor of chemistry, University of Virginia, "The Magneto-optic Method of Chemical Analysis."

The committee also had worthy applications for assistance from five other persons which could not be granted because of lack of funds. Applications would have required more than twice the amount of money available for distribution and so the committee, much against its wishes, was obliged, not only to refuse some requests entirely, but also to reduce the amounts granted to most of the others.

E. C. L. MILLER,
Secretary

SEMICENTENNIAL MEETING OF THE AMERICAN ORNITHOLOGISTS' UNION

THE fiftieth anniversary meeting of the American Ornithologists' Union will be held from November 13 to 16 in New York, at the American Museum of Natural History, 77th Street and Central Park West, where the union was originally organized in 1883. The organization now has about 2,000 members, including 74 who have maintained their membership for 40 years or more.

The headquarters will be at the Hotel New Yorker, 8th Avenue and 34th Street, where the business meetings will be held on Monday.

The public meetings, beginning on Tuesday, November 14, will be held at the American Museum and will continue three days from 9 A. M. to 5 P. M. The program contains more than 60 papers, including the latest reports on work in the field and in the museum, illustrated by specimens, lantern slides, direct color photographs and "sound pictures."

The award of the Brewster Medal, made biennially to the author of the leading work on the birds of America which has appeared during the last six years, will be announced at this meeting.

In honor of the occasion the union has prepared a special volume containing a series of papers showing "Fifty Years of Progress in American Ornithology" since the organization of the union.

The local committee on arrangements has brought together a carefully selected exhibit of bird art, including paintings, water colors, photographs, drawings and sculpture, which will remain on exhibition for some time after the meeting.

The annual dinner will be held at the Hotel New Yorker on Wednesday evening. Public sessions trips have been arranged on Friday and Saturday to the New York Zoological Park, to the Jones Beach Bird Sanctuary, Long Island, and to the Roosevelt Bird Sanctuary at Oyster Bay, Long Island.

SCIENTIFIC NOTES AND NEWS

DR. HARVEY CUSHING, now John W. Sterling professor of neurology in the Yale School of Medicine, received the degree of doctor *honoris causa* on November 4 during ceremonies which attended the reopening of the University of Paris. Among those present were President Lebrun and Minister of Education de Monzie.

AT the ceremonies in commemoration of the fiftieth anniversary of the founding of the Graduate School of the University of Pennsylvania, Dr. Joseph S. Ames, president of the Johns Hopkins University, received the degree of doctor of laws; Dr. Luther P. Eisenhart, dean of the Graduate School of Princeton University, the degree of doctor of science, and Dr. Frederick J. E. Woodbridge, Johnsonian professor of philosophy at Columbia University and formerly dean of its Graduate School, the degree of doctor of letters.

THE honorary degree of doctor of science was conferred on Dr. Charles A. Kraus, research professor of chemistry at Brown University; on Lemuel F. Smith, professor of chemistry at Kalamazoo College; on Vernor C. Finch, head of the department of geography at the University of Wisconsin, and on Leroy J. Buttolph, physicist with the General Electric Vapor Lamp Company of Hoboken, New Jersey, by Kalamazoo College in connection with its centennial celebration on October 13.

ACCORDING to *Industrial and Engineering Chemistry,* Henry Arnstein has been awarded first prize by the Uruguayan government for bids for designing, constructing and putting in operation an agricultural distillery and an industrial alcohol plant manufacturing alcohol, recovering yeast, liquid and solid carbon dioxide, corn oil and cattle feed. Dr. Arnstein has recently sailed for Johannesburg, South Africa, to initiate a program for utilizing the surplus farm crops of that country.

DR. D. C. WARREN, poultry geneticist at the Kansas State College, has been awarded the 1933 $100 prize of the Poultry Science Association for outstanding research on the domestic fowl during the year.

PROFESSOR VON LICHTENBERG, director of the urological department of the Hedwig Hospital, Berlin, has been awarded the gold medal of the International Society for Urology.

DR. MAX HEINRICH FISCHER, physiology, Berlin, has been elected a corresponding member of the Royal Academy of Medicine, Rome.

DR. ARNO B. LUCKHARDT, professor of physiology at the University of Chicago, gave the presidential address on "Biological Reaction to Ethylene Anesthesia" before the Associated Anesthetists of the United States and Canada, meeting in Chicago on October 17. He was also elected honorary president of the International Anesthesia Research Society.

DR. A. HAMILTON RICE has been elected president of the Museum of French Art, New York City.

F. A. SILCOX has been appointed as chief forester of the Forest Service to succeed the late Major R. Y. Stuart. Mr. Silcox has been engaged in handling labor problems in shipyards and as director of indus-

trial relations for the New York Employing Printers' Association. He was formerly in the Forest Service, entering as a ranger in Colorado.

HUGH H. BENNETT, formerly with the Bureau of Chemistry and Soils of the Department of Agriculture, has been named chief of a new bureau devoted to control of soil erosion in the Department of the Interior. The new unit, to be known as the Division of Erosion, will operate with a fund of $5,000,000 allotted by the Public Works Administration. In addition to studying erosion, it will lend its efforts to bettering flood conditions.

DR. BENJAMIN WHITE, the director of the Division of Biologic Laboratories of the Massachusetts Department of Public Health, has retired because of ill health, and Dr. Elliott S. Robinson has been promoted to fill the vacancy. Dr. Roy F. Feemster, formerly of the Division of Communicable Diseases, has been made assistant director.

KNOWLES A. RYERSON has been appointed chief of the Bureau of Plant Industry, effective January 1. Mr. Ryerson will succeed Dr. W. A. Taylor, who retires the first of the year after forty-two years' service with the Department of Agriculture, twenty of which have been as head of the bureau. Dr. Taylor reached the retirement age on July 1, but the president granted an extension of six months at the urgent request of Secretary Wallace. Mr. Ryerson is now in charge of the Division of Foreign Plant Introduction. His promotion to the position of chief is announced now so that he may have an opportunity to work for the next few weeks with Dr. Taylor on budgetary and administrative problems before he assumes his new work.

H. R. TOLLEY, professor of agricultural economics and agricultural economist and director of the Giannini Foundation of the University of California, has been appointed chief of the section of special crops in the Agricultural Adjustment Administration. In this capacity he will organize the relief program for crops not listed as basic commodities under the act, a program centering largely around marketing agreements.

DR. HENRY H. PIXLEY, instructor in mathematics in the College of the City of Detroit, has been granted leave of absence to permit him to accept a position as mathematical economist in the Division of Economic Research and Planning of the National Recovery Administration.

DR. C. P. GILLETTE, for forty-three years head of the department of entomology of the Colorado Agricultural College and director of the Experiment Station from 1910 to 1932, terminated active connection with the college and station on July 1. It is expected that he will continue his research work at the college. A. M. Binkley, associate professor of horticulture and associate horticulturist, has been appointed acting head of the department, with Dean E. P. Sandsten, director of the station, retaining the position of professor of horticulture and state horticulturist.

UNDER a reorganization program recently approved by the Board of Trustees of Clemson College and the South Carolina Agricultural Experiment Station, H. W. Barre, who has been director of the station for sixteen years, has also been appointed dean of the School of Agriculture. G. H. Aull, for twelve years assistant director of research, has been appointed agricultural economist and assistant director of the station.

H. H. KILDEE, head of the department of animal husbandry and vice-dean of the division of agriculture of the Iowa State College and Experiment Station, has been appointed dean of agriculture; M. D. Helser, head of the meat subsection of the station, has been appointed dean of the junior college, and Dr. R. E. Buchanan, head of the department of bacteriology and dean of the graduate school, director of the station. President R. M. Hughes is for the present continuing as acting director of the division of agriculture, with George Godfrey as assistant.

DR. HUNTINGTON WILLIAMS, Baltimore health commissioner, has been appointed professor of hygiene and public health at the University of Maryland School of Medicine.

DR. GEORGE H. HANSMANN, assistant professor of pathology at the State University of Iowa College of Medicine, has been appointed associate professor at Georgetown University School of Medicine, Washington. Dr. James A. Gannon has resigned as associate professor of surgery at Georgetown University, after twenty-five years' association with the department.

M. JEAN DUFAY, astronomer of the observatory at Lyons, has been appointed director to succeed M. Mascart.

DR. RICHARD BRAUER, formerly professor of mathematics at the University of Königsberg, has accepted an invitation extended to him by the University of Kentucky to hold a visiting professorship for the current academic year. He is expected to reach Lexington about November 15. The invitation was made possible by the Emergency Committee in Aid of Displaced German Scholars, and by the Jewish people of Lexington, who have contributed funds for Professor Brauer's salary.

DR. FRANZ BLUMENTHAL, professor of dermatology at the University of Berlin, has accepted a professorship offered to him by the faculty of medicine at Belgrade. Since 1917 he has been director of the Institute for Cancer Research in Berlin and general

secretary of the German Society for Cancer. He will continue his experimental work on cancer at the laboratories of the Institute of Pathology at Belgrade, which was formerly under the direction of the late Professor Georges Joannovič.

DR. J. R. KATZ, of the University of Amsterdam, has been spending his vacation in the United States. While in New York he lectured before the New York Section of the Cereal Chemists on "Starch, its Gelatinization and Retrogradation." He also delivered lectures at the Fleischmann Laboratories on "Chemical Changes in the Gluten during the Fermentation of the Dough" and "X-ray Spectrography of High Molecular Substances."

THE first Harry Burr Ferris lecture in anatomy at Yale University was delivered on the evening of October 27 by Dr. Bradley M. Patten, associate professor of embryology and histology at Western Reserve University. This lecture was the first annual lecture to commemorate forty-two successive years of teaching of anatomy by Dr. Ferris at Yale. The subject of the lecture was: "The First Heart Beat and the Beginning of the Circulation of the Blood of the Embryo—Studied with Micro-Moving Pictures."

DR. ARTURO CASTIGLIONI, professor of the history of medicine, University of Padua, Italy, gave the third course of lectures under the Hideyo Noguchi Lectureship of the Johns Hopkins University School of Medicine. The theme of the lectures was "The Renaissance of Medicine in Italy," and following are the individual titles: October 23, "The Dawn of Renaissance in the Life, Art and Science of Italy—The Thought of Leonardo." October 25, "The Flowering of Medical Studies at the Italian Universities, from Berengario to Cesalpino." October 27, "The Legacy of Scientific Renaissance and the Main Currents of Medical Thought from Fracastoro to Galileo." In 1929, Dr. Emanuel Libman, New York, gave $10,000 to establish the lectureship in honor of Dr. Noguchi.

DR. J. C. DRUMMOND delivered a course of Harben lectures on vitamins at the Royal Institute of Public Health, London, on October 9, 10 and 11.

THE October lecture on the Smith-Reed-Russell series at the School of Medicine, George Washington University, was delivered by Professor W. W. Cort, of the School of Hygiene and Public Health of the Johns Hopkins University, who spoke on "Recent Developments in our Knowledge of Hook-Worm Disease." The November lecture on this series will be given by Professor James W. Jobling, College of Physicians and Surgeons, Columbia University. At the annual banquet of the society, which was held at the University Club on October 20, an address was delivered by Dr. William Charles White, chairman of the Committee on Research of the National Tuberculosis Association. On this occasion new faculty and student members were inducted into the society.

ANNOUNCEMENT is made at Harvard University that the Board of Overseers has created a new visiting committee to visit the Stillman Infirmary and University Clinic. The new group brings to fifty-two the visiting committees selected by the Board of Overseers to keep divisions and departments of the university in active communication with interested authorities throughout the country. The chairman of the committee is Dr. Daniel F. Jones, '92, of Boston, surgeon-in-chief at the Palmer Memorial Hospital. The remaining members follow: Dr. George H. Bigelow, '13, of Boston, a member of the staff at the Massachusetts General Hospital; Dr. Eugene F. DuBois, '03, professor of medicine at the Cornell University Medical College; Dr. Channing Frothingham, '02, of Boston, physician-in-charge at the Faulkner Hospital; Henry S. Grew, of Boston; Dr. Edward B. Krumbhaar, professor of pathology at the University of Pennsylvania, and Dr. Ernest G. Stillman, of New York City.

AT a recent meeting of the board of managers, the following were elected to constitute the editorial board of *The Journal of Nutrition:* Dr. Thorne M. Carpenter, Boston; Dr. Edward P. Cathcart, Glasgow; Dr. Eugene F. DuBois, New York; Dr. Ernest B. Forbes, State College, Pennsylvania; Dr. Elmer V. McCollum, Baltimore; Dr. Lafayette B. Mendel, New Haven; Dr. Harold H. Mitchell, Urbana; Dr. John R. Murlin, Rochester; Dr. Mary S. Rose, New York; Dr. Henry C. Sherman, New York; Dr. Harry Steenbock, Madison. The editorial board will select a managing editor from its own members and will determine the scientific policy of the journal. The journal will appear monthly in a new cover bearing a portrait of von Liebig on the first page. Two volumes a year will be issued at $5.00 per volume. It will be the official organ of the American Institute of Nutrition, of which Dr. Lafayette B. Mendel, of Yale University, is president; Dr. Henry C. Sherman, of Columbia University, is vice-president, and Dr. John R. Murlin, of the University of Rochester, is secretary-treasurer. The board of trustees includes the above-named officers and Dr. Mary S. Rose, of Columbia University, and Dr. Eugene F. DuBois, of Cornell University Medical College.

WITH the November number, the editors of *Scripta Mathematica* announce that the policy begun in Volume I will be continued, of appealing to the laymen interested in the philosophy, history and exposition of mathematics, as well as to the trained mathematician. This journal, said to be unique in its treatment of mathematics, begins its second year with the publication of the autumn issue, under the editorship of Professor Jekuthiel Ginsburg, of Yeshiva

College and Columbia University. The editorial board is announced to be the same as last year, including Professors Cassius Jackson Keyser and David Eugene Smith, of Columbia University; Professor Raymond Clare Archibald, of Brown University; Professor Louis Charles Karpinski, of the University of Michigan; Professor Lao Genevra Simons, of Hunter College, and Professor Gino Loria, of the University of Genoa. "Notes and Queries" will again be edited by Professor Archibald. It is also expected to print hitherto unpublished manuscripts now in university and private libraries in this country.

DISCUSSION

AGE OF FITCHBURG GRANITE

WHEN the Tufts group visited the quarries at Fitchburg last spring they were particularly asked to keep an eye out for radio-active minerals which one can recognize by the cracks which radiate from them. A number of specimens were obtained, but they were mostly allanite.

One piece, however, the spinthariscope showed to be much more radio-active and proved to be uraninite. It was only about four millimeters in diameter, but I was able to dig out about 30 milligrams and send to Dr. Friedrich Hecht, 38 Währingerstrasse, Vienna, Austria, who was able to make on 18 milligrams by micro-chemical methods the accompanying analysis. I am sending this to SCIENCE for a number of reasons.

MICROANALYSIS OF FITCHBURG URANINITE

Used for total analysis : 18 mg.
Used for determination of H_2O: 6 mg.

	Per cent.
Insoluble residue	27.39
(of which SiO_2)	(25.48)
PbO	2.72
(Pb)	(2.52)
$Fe_2O_3 + Al_2O_3$	not determined
Rare earths	1.85
ThO_2	3.86
(Th)	(3.39)
U_3O_8	59.19
(U)	(50.20)
CaO	0.84
MgO	0.15
H_2O (−110°)	0.27
H_2O (110–300°)	2.90
Loss on ignition	.....
Alkalies	present, but not determined

$Pb/U + 0.25.Th = 0.049$,

Analysts: F. Hecht and Edith Kroupa.

There is so little Th that using the factor 0.36 instead of 0.25 will make no appreciable difference. Allowing for AcD and ThD we would get an age:

$15{,}600 \log(1 + (RaG = 2.37)/(U = 50)) = 366$ million years

In the first place, I should like to call attention to the fact that with micro-chemical methods a geologically useful analysis can be made on such small quantities, and I think Dr. Hecht would be glad to arrange for such analyses by coworkers for others, and by no means solely on radioactive minerals. Methods have been developed for a variety of compounds.

In the second place the analysis indicates that this granite is much older than I had expected (360 million years) and akin to that at Branchville, Conn., from which a uraninite has been analyzed by Hillebrand (N.R.C. Bulletin 80, p. 341). This, however, agrees with what Professor Berkey had thought and shows what important help may be given by such research.

Finally, as one swallow does not make a summer it would be desirable to have analyses made of other such minerals, and I would like to call attention to the possibility of so doing even from such small quantities. It would be very interesting to have analyses from New Hampshire granites, and such minerals should be found in the quarries north of Keene.

ALFRED C. LANE,
Chairman, N.R.C. Committee on the Measurement of Geological Time

"EXPANSION AND CONTRACTION" OF CHROMATOPHORES

SUMNER,[1] in a recent article in this journal, contends that a large majority of investigators interested in changes in color in vertebrates hold that the movement of pigment granules in the chromatophores is not due to "expansion or contraction" of the chromatophores, but that they continue to use this expression in spite of the fact that its meaning is not at all in accord with their view. To remedy this incongruous situation, he proposes to substitute "chromatosome" (pigment body) for "chromatophore." He says: "My suggestion is that we continue to employ the terms 'expansion' and 'contraction,' since something obviously does expand and contract, but that we credit these movements to the things that actually do expand and contract, namely, the pigment-masses within the cells."

It is well known that the colored substance in the chromatophores in the vertebrates is in the form of numerous discrete granules and that these granules move on definite paths through the cytoplasm out into the various branches of the chromatophores under certain conditions, and on the same paths back into

[1] F. B. Sumner, "Why Do We Persist in Talking about the 'Expansion' and 'Contraction' of Chromatophores?" SCIENCE, 78: 283–4, 1933.

the central part under other conditions. The motor mechanism involved in this movement is doubtless located in the colorless cytoplasm through which the granules move. It certainly is not in the colored substance itself. In other words, while it is evident that the pigment masses (chromatosomes) change enormously in form, there is no evidence indicating that they *per se* change in size, *i.e.*, expand and contract, and that the change is due to processes within them. It seems to me therefore that the phrase "expansion and contraction of these masses" (chromatosomes) describes the phenomena in question but little, if any, more accurately than the phrase "expansion and contraction of chromatophores."

Under the conditions which induce movement of the pigment granules out into the branches of the chromatophores they become distributed through a relatively large space, and under those which induce movement in the opposite direction they become concentrated in a relatively small space, and their function is obviously specifically associated with the space they occupy, *i.e.*, the extent of this distribution. I would therefore suggest the phrase "distribution and aggregation of pigment granules" (melanin, xanthine, *et al.*) in place of "expansion and contraction of chromatophores" or "chromatosomes." In a paper[2] and in lectures on the subject, I have used the verbs "spread out" and "aggregate" to designate respectively movement out into the branches and in the opposite direction. These phrases express precisely what occurs, and until more is known about the mechanics of the processes involved, I see no need for any others.

S. O. MAST

THE JOHNS HOPKINS UNIVERSITY

SLICKENSIDES

IN the fireclays and other underclays beneath the beds of coal in the Pennsylvanian system of the United States, the countless millions of slickensides command the interest of the geologist, who studies them, and provoke the question as to their origin. Many of them, perhaps most of them, are but a fraction of an inch in length and in no wise involve the overlying or underlying beds. Neither does any one of them cut the whole of the clay bed in which they exist. They must have been formed by the material on one side of each of these minute fractures slipping past the material on the opposite side. But even so, the motive force is not evident; neither is the manner in which it operated, because these small fracture surfaces extend in all directions and dip at any angle, even in the same mass of clay.

Where the slickenside surface involves the whole of a bed or cuts across two or more beds no such problem exists. The slickenside surface was produced by the pressure of one side of the fractured surface against the other side as the two parts moved away from each other along the faulted surface. Such slickenside surfaces are most easily produced in plastic clays and clay shales and most difficultly formed in pure quartz sandstones, as in Wisconsin, where the friction had to be sufficiently great to fuse the quartz grains into a natural enamel, but enamel which still preserved its striae.

Because of the problem involved in the origin of these slickensides in the fireclays and underclays, it was with keen interest that, in 1929, slickensides in the making were observed in the delta of the Mississippi River off the mouth of South Pass. Mud lumps are numerous here. They are shoved up to the surface and a few feet above it rather suddenly, instantly to be attacked by the waves and worn down to gulf level. One such mud lump, tied to west jetty-end by a sand spit or sand bar, was being undercut by the waves on the gulf side. As the waves cut back, the unsupported overlying mass of plastic clay slumped irregularly back into the gulf, producing the most beautiful slickensides imaginable. Of course these slickenside surfaces, at the moment of their development, dipped steeply downward, but the undercutting of a partly slumped mass could produce a new set of slickenside surfaces intersecting the earlier set at any angle whatsoever, just as these surfaces do in the fireclays and underclays.

The process of development of these slickensides in the mud lumps of the Gulf of Mexico suggests that at least some of the slickensides in the fireclays and underclays could have been formed by the waves in the Pennsylvanian swamps attacking the material of the soil in which the coal vegetation grew. The process could not produce slickensides in those fireclays and underclays in which the roots and root impressions of the coal vegetation still extend downward into the clay, but it would be interesting and instructive to observe whether or not clays penetrated by plant roots have slickenside surfaces intersecting at all angles; whether or not they have slickensides of steeply inclined surfaces only; or whether or not the clays penetrated by roots have fewer slickenside surfaces than have the clays free from such roots and root impressions.

WILLIAM CLIFFORD MORSE

MISSISSIPPI STATE COLLEGE

[2] S. O. Mast, "Changes in Shade, Color and Pattern in Fishes, and Their Bearing on the Problems of Adaptation and Behavior, with Especial Reference to the Flounders Paralichthys and Ancylopsetta," *Bulletin of the Bureau of Fisheries*, 34: 177–238, 1914. Albert Kuntz, "The Histological Basis of Adaptive Shades and Colors in the Flounder *Paralichthys albiguttus*," *Bulletin of the Bureau of Fisheries*, 35: 1–28, 1915.

AN ANATOMICAL EXPLANATION OF THE NORTHWEST CONIFEROUS CLIMAX FORESTS

INASMUCH as the summers of the Pacific Northwest are dry, while the winters are wet and mild, it has been suggested that the evergreen conifers have come to form the climax forests of that region because they grow during the winter months. Dr. D. T. MacDougal,[1] after dendrographic measurements, has said of the Monterey pine in California that "Growth was continuous for one period of three years." Over a considerable period of time the writer has attempted to gather anatomical evidence showing that the conifers of Oregon are active in the winter when the deciduous trees are resting.

This study was begun in 1914 with material collected in western Oregon during the winter months and has been continued at more or less regular intervals up to the present time. Beginning in 1921, material was collected in the summer and sometimes once a month for an entire year. Specimens from Kentucky were occasionally examined for purposes of comparison, since the Kentucky climax forests are dominantly deciduous.

Phloem, cambium and adjacent xylem of the following Oregon trees were examined: *Pseudotsuga taxifolia, Abies grandis, Libocedrus decurrens, Thuja plicata, Pinus ponderosa, Taxus brevifolia, Quercus garryana, Acer macrophyllum, Salix schouleriana.* For comparison similar material was used from the following Kentucky trees: *Pinus rigida, Picea rubra, Juniperus virginiana, Tilia americana, Ulmus americana, Celtis occidentalis, Quercus velutina.* Results were fairly consistent except under conditions of abnormally cold weather.

The Oregon conifers studies from October to February showed in radial view from 3 to 10 sieve tubes free from callus and an undifferentiated cambium region 5 to 14 cells wide. The deciduous trees at this time showed no open sieve tubes, and the cambium was 3 to 5 cells wide.

During July and August in the conifers from 1 to 4 immature sieve tubes were free from callus, and the undifferentiated cambium was 5 to 6 cells wide. At this time, in the deciduous trees there were either no open sieve tubes, or from 2 to 3 immature ones, while the cambium was 6 to 9 cells wide.

In the Kentucky conifers in winter there were no open tubes, though occasionally there was one partially free, and the cambium was from 4 to 5 cells wide. The deciduous trees there showed no open tubes.

Since the absence of callus pads in sieve tubes together with a wide undifferentiated cambium is accepted as evidence of activity, it may be assumed that the Oregon conifers were active during most of the winter season, while the deciduous trees were quiescent. In the late dry summer both types were practically inactive. In Kentucky, on the other hand, both conifers and deciduous trees were inactive in winter.

It was interesting to note that the winter activity of the Oregon conifers seems to be confined to three phases: food manufacture, some phloem development and some apical elongation. As far as was observed, no new xylem cells were formed in the main trunk at this time.

It seems then that the Oregon deciduous trees, having leaves for only two or three months of that part of the year when water is sufficiently abundant to carry on photosynthesis, must have inevitably lost out in their competition with the evergreens which are active to a certain extent for nine or ten months of the year.

A complete detailed account of this study will be published shortly.

ANSEL F. HEMENWAY

UNIVERSITY OF ARIZONA

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

MINUTES OF THE EXECUTIVE COMMITTEE

THE fall meeting of the executive committee was held on October 14 and 15 at the Cosmos Club in Washington. Those present were J. McKeen Cattell, *chairman*, D. R. Curtiss, Philip Fox, B. E. Livingston, Henry N. Russell, Henry B. Ward, E. B. Wilson and A. F. Woods.

The first session was devoted to an extended discussion of major problems of policy. Plans were considered for supporting the prosecution of research under federal auspices, for maintaining and extending the membership of the association, for utilizing the funds available and for aiding effectively the various movements for national recovery. No formal action was taken on these items.

Specific questions on which action was recorded were the following:

(1) The treasurer's financial report for 1933 was received and read. It was ordered audited and referred to the Boston meeting of the council.

(2) The treasurer's budget for 1934 was presented, and after consideration referred to the council.

[1] Carnegie Institution Yearbook, No. 30, 1930–31, p. 243.

(3) The permanent secretary's financial report for 1933 was presented and ordered audited, after which it is to be laid before the council.

(4) The permanent secretary's budget for 1934 was presented and ordered referred to the council at the Boston meeting for final action.

(5) The director of the press service, Austin H. Clark, reported on arrangements for the Boston meeting and discussed with the executive committee plans of the work in general and in relation to the coming meeting.

(6) The director of exhibits, F. C. Brown, reported on preparations for the Boston exhibit, and was authorized to make a trip to Chicago to ascertain if any exhibits at the Century of Progress were suitable and available for future exhibits of the association.

(7) It was voted that Dr. Henry Crew be added to the present exhibit committee.

(8) Dr. T. H. Morgan was named the association's representative on the committee of review, as provided in the deed of trust of the Marine Biological Laboratory.

(9) The report of the committee on patents, trademarks and copyrights was presented, with the recommendation that it be published by the association. The executive committee instructed the permanent secretary to provide for printing the report as the first in a new series. The matter of format and other details was left in the hands of the chairman and permanent secretary.

(10) The executive committee accepted an offer from The Science Press to print and sell the report of the committee on patents, trademarks and copyrights.

(11) The permanent secretary was authorized to secure estimates for printing the next volume of summarized proceedings.

(12) Under the terms of the emeritus annual membership fund established last year, the following were selected as members for the year 1934: Dr. Beverly T. Galloway, U. S. Department of Agriculture, Washington, D. C.; Professor Clarence P. Gillette, Fort Collins, Colorado; Professor John Lane Van Ornum, Washington University, St. Louis, Missouri.

(13) The application of the Minnesota Academy of Science for affiliation was approved and referred to the council for information.

(14) A communication was presented from Dr. Arnold Kruckman, of the Tennessee Valley Authority, asking the aid of the association in acquiring further knowledge of the territory covered by the authority. The executive committee advised that if possible a symposium on various phases of conservation be organized for the Boston meeting and that such symposium bear upon the fundamental features of the project. The permanent secretary was instructed to write accordingly and to state that the association desires to be of service in carrying out the plans in the Tennessee Valley.

(15) Reports of the Fifth Pacific Science Congress were presented by the delegates, C. A. Kofoid and T. W. Vaughan. The committee expressed its appreciation of the work of these delegates.

(16) The committee adjourned at 3:30 P. M. to meet in Boston, Tuesday evening, December 26, at the Statler Hotel.

HENRY B. WARD
Permanent Secretary

SCIENTIFIC APPARATUS AND LABORATORY METHODS

PHYSIOLOGICALLY BALANCED CULTURE SOLUTIONS WITH STABLE HYDROGEN-ION CONCENTRATION

ONE of the important problems in the culture of higher plants in artificial media is that of maintaining the hydrogen-ion concentration of the culture solution within limits favorable to growth. Even when high concentrations of dissolved phosphates are used as chemical buffers, the solution may need to be passed through the culture vessel at a very high rate if the pH value is to be held within a narrow zone. The purpose of this note is to emphasize the advantage of employing physiologically balanced solutions which, under the influence of absorption and excretion of substances by the plant, tend to maintain a constant hydrogen-ion concentration.

The observations of several investigators, particularly those of Jones and Shive,[1] have clearly indicated that this means of stabilizing the reaction of culture solutions may be of considerable practical value. The effectiveness of this method has recently been demonstrated in a detailed study of the influence of the ionic ratio of NO_3 to NH_4 on the reaction change produced by wheat plants during various phases of their development. Initial pH values of 4.3, 5.1 and 6.0 were secured by means of suitable proportions of H_3PO_4, KH_2PO_4 and K_2HPO_4. A wide range of NO_3/NH_4 ionic ratios was obtained by varying the proportions of KNO_3 and $(NH_4)_2SO_4$, KNO_3 and NH_4NO_3, and $Ca(NO_3)_2$ and NH_4NO_3; but the total nitrogen concentration was kept the

[1] L. H. Jones and J. W. Shive, "Influence of Wheat Seedlings upon the Hydrogen-ion Concentration of Nutrient Solutions," *Bot. Gaz.*, 73: 391–400, 1922.

same in all solutions. Twenty-five wheat plants were grown in each culture vessel containing 8,600 cc of solution. The solutions were renewed every eight days. Daily records were made of the hydrogen-ion concentrations of the solutions during a culture period of 102 days.

It was found that with low NO_3/NH_4 ratios the pH values of the solution decreased rapidly under the influence of the plants and approached in extreme cases a pH value of 3.0. With high ratios, on the other hand, the pH values increased rapidly, tending to reach a limiting value of 6.5. When a NO_3/NH_4 ratio of suitable value was used, however, a physiologically balanced solution was obtained in which the hydrogen-ion concentration tended to remain approximately constant during the eight-day period between solution renewals. By balancing the partial concentration of NO_3 (the absorption of which removes H-ions from the solution) against that of NH_4 (the absorption of which removes OH-ions from the solution), the various conditions that tend to decrease the acidity may be exactly opposed by conditions that tend to increase the acidity. This method was found to be far more effective than that of attempting to stabilize the solution by greatly increasing the phosphate buffer content.

To maintain a higher pH value, it was necessary to use a higher ratio of NO_3 to NH_4. As the plants grew older, they gradually changed in their ability to alter the reaction of the solution. For the most accurate control of the pH value throughout the life cycle of the plants, it was therefore necessary to employ progressively lower NO_3/NH_4 ratios. Nevertheless, an approximately constant pH value could be maintained throughout the culture period by using a suitably selected intermediate NO_3/NH_4 ratio. Thus a very satisfactory stabilization of the pH value was obtained when NO_3/NH_4 ionic ratios of 50/50, 85/15 and 95/5 were used for maintaining pH 4.3, 5.1 and 6.0, respectively. The average changes in reaction after 8 days of contact with the roots were 0.23 pH, 0.21 pH and 0.08 pH, respectively. The composition of the solution for pH 5.1 is as follows: 0.00670 m KNO_3, 0.00059 m $(NH_4)_2SO_4$, 0.00255 m KH_2PO_4, 0.000079 m K_2HPO_4, 0.00394 m $CaCl_2$, 0.00263 m $MgSO_4$, 0.00005 m $FeSO_4$, 0.00005 m $K_3C_6H_5O_7$. In addition the solution contains 0.11 ppm. Mn, 0.07 ppm. Zn, 0.05 ppm. B, 0.002 ppm. Cu, 0.09 ppm. Al, 0.005 ppm. Li, 0.12 ppm. Na, 0.01 ppm. As, 0.1 ppm. Si, 0.01 ppm. Ni, 0.01 ppm. Co and 0.01 ppm. I.

The results of this study demonstrate clearly that the use of a physiologically balanced culture solution provides an effective and practicable means of stabilizing the hydrogen-ion concentration of the solution, and they indicate that excellent growth of the plants may be secured in a culture solution of this type if due attention is given to the total concentration as well as to the relative proportions of the solution constituents. This method may be recommended for many different kinds of physiological studies in which culture solutions with controlled pH values are required. The general utility and significance of physiological balance as a means of stabilizing the reaction of culture media appear to be worthy of much greater emphasis than they have been given in the literature of physiology, pathology, mycology and bacteriology.

SAM F. TRELEASE
HELEN M. TRELEASE

COLUMBIA UNIVERSITY

SPECIAL ARTICLES

THE EVOLUTION OF CEREBRAL LOCALIZATION PATTERNS[1]

THE localization of functions within the brain has been a topic of acute controversy since the beginning of inquiry into the organization of the central nervous system. Without attempting a review of the observations, experiments and speculations in this field, it is evident that the problem has recently entered a new phase with the elaboration of new methods of inquiry and new fundamental conceptions of nervous processes. The divergencies of opinion are to-day more acute and dogmatic than ever before, ranging all the way from a modernized phrenological localization in mosaic patterns of mental faculties of one sort or another to the equally ancient denial of any localization whatever in the cerebrum. On the last point an experimental psychologist has recently written, "Physiology must abandon any theory of cortical activity that rests upon localization of function."

The anatomist, embryologist, physiologist, psychologist and clinician views the problem from his own angle and in the light of his own experience. Too often his general conclusions are derived only from the meager data visible to him within his own contracted horizon. There is truth in each of these partial views, and before a satisfactory solution can be hoped for we must all learn to liberalize our own opinions by looking at the question as judiciously as we can from all points of view. This may justify the presentation of an aspect of the problem which has received scant attention—the phylogenetic approach.

[1] This research was aided by a grant to the University of Chicago by the Rockefeller Foundation.

One major difficulty in the formulation of any scheme of localization arises from failure to recognize that different types of sensory experience involve very diverse kinds of adjustment to what is going on in the environment, and no single formula can be expected to apply to all of them. Contrast, for instance, the three sensory systems, smell, hearing and vision. Odors have quality and intensity, but no well-defined discrimination in terms of either space or time. The central connections of the olfactory nerve show a minimum of localization, with a diffuse spread, and a maximum of apparatus of summation, intensification and non-specific activation and reinforcement of other sensory-motor systems. Hearing is essentially a time-sense with imperfect localization in space, and the central connections of the auditory nerve are not spread out in space in patterns related with the arrangement of the sensory receptive cells of the cochlea. It is evident that tone analysis is effected by a type of apparatus which does not require that the excitation of specific receptive cells of the organ of Corti be registered centrally in separate places. Vision, on the other hand, is preeminently a space-sense, and here we do find a very precise localization of central tracts and nuclei from the retina to the visual cortex.

The problem of anatomical localization of function within the brain is radically different in these three sensory systems, and it is not to be expected that the pattern of localization which is so clearly shown in the visual system of conductors will be repeated in the auditory and olfactory systems. In primates the various loci of the visual field are accurately projected by the dioptric apparatus upon the retina, the various quadrants of the retina are known to be projected upon precisely bounded parts of the lateral geniculate body, and these in turn are again projected upon definite sectors of the striate area of the cortex. It is probable that the nervous pathway from every point on the retina maintains some measure of individual distinctness up to its discharge into a specific locus of the cortex. This type of localization in space is not required for the sense of hearing, a temporal sense, and in fact the auditory pathway does not show it.

Since the visual pathway is more precisely localized within the brain than that of any of the other senses, it may contribute to our understanding of cerebral localization in general to examine the phylogenetic history of the thalamic visual center—the lateral geniculate body. This survey shows a gradual emergence of this specific and sharply localized center from a non-specific area of central gray and it may illuminate the relation between sharply localized and more dispersed functions in general.

We take our departure from the primitive generalized Amphibia—Necturus and Amblystoma—where the thalamus is very small and undifferentiated. Figs. 1 and 2 give the general orientation and show that the thalamus proper, lying between

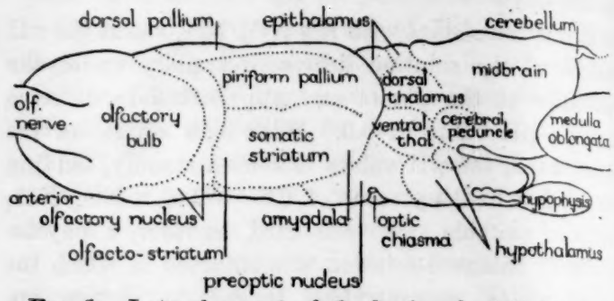

FIG. 1. Lateral aspect of the brain of adult *Necturus maculosus* upon which the boundaries of some of the larger cellular areas are projected in dotted outline. ×6. Figures 1 to 3 are taken from the author's Morphogenesis of the Brain, *J. Morph.*, vol. 54, 1933, pp. 233–258.

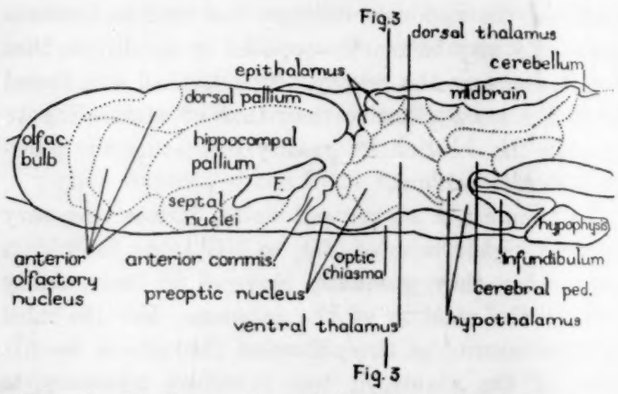

FIG. 2. Median section of the brain of Necturus upon which the outlines of some of the areas of gray substance are similarly indicated. Most of these boundaries are marked by ventricular sulci. In the midbrain and betweenbrain the section is median; in the cerebral hemisphere the plane of section is slightly to one side of the midplane, better to show the relations of the interventricular foramen (*F*) to surrounding gray areas. The approximate plane of figure 3 is indicated.

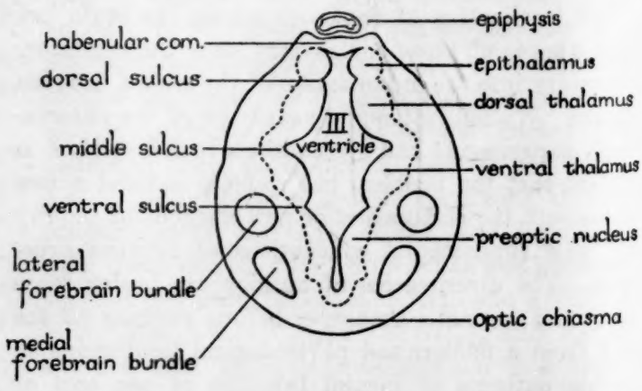

FIG. 3. Transverse section through the diencephalon of Necturus. The outline of the gray substance is indicated by broken lines.

the epithalamus above and the hypothalamus below, is very small. It is divided by a sharp ventricular sulcus into dorsal and ventral parts. The larger ventral part is the precursor of the subthalamus of human anatomy and is a motor adjustor interpolated between the corpus striatum and cerebral peduncle, as in man. The very meagerly developed dorsal thalamus is the precursor of the entire sensory thalamus of mammals. The relations of these parts as seen in cross-section are shown in Fig. 3.

The plan of organization of this primitive sensory thalamus is shown very diagrammatically in Fig. 4.

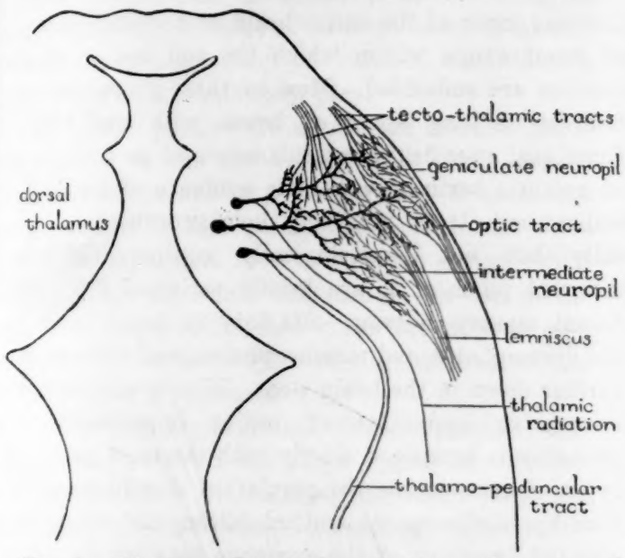

FIG. 4. Diagram of typical connections of neurons of the dorsal, or sensory, thalamus of Necturus, as seen in cross-section. Three neurons of this area are drawn. Their cell bodies lie in a deep periventricular layer of gray. Their dendrites spread widely throughout the white substance, where they are in synaptic connection with terminals or collaterals of various sensory tracts. Their axons may enter the thalamo-peduncular tract (for thalamic reflexes), or they may enter the thalamic radiation which ascends to the cerebral hemisphere. The whole dorsal thalamus is a "nucleus diffusus thalami."

The cell bodies of all neurons are densely crowded in a periventricular gray layer; that is, they retain the embryonic position and no special nuclei are differentiated. Their dendrites and axons pass outward into a superficial white layer, where most of the synaptic junctions are found. These dendrites arborize widely and those of a single cell may spread throughout the entire field of the sensory thalamus. Here they may be activated by terminals of the optic tract, by various lemniscus systems from medulla oblongata and spinal cord, and from the midbrain roof by tecto-thalamic tracts. A thalamic neuron may be activated by any one of these afferent systems or by several of them in various combinations.

The sensory thalamus may be characterized as a nucleus diffusus. Its neurons are not segregated into nuclei each with its own specific connections, as in man. Nevertheless, in the white substance there is an incipient localization, for the incoming fibers tend to end in local fields of neuropil. Thus collaterals from the optic tract arborize in a superficial area of neuropil and they do not pass beyond it. This is clearly the precursor of the lateral geniculate body (Fig. 4, geniculate neuropil). There are few, if any, neurons which are related exclusively with this "geniculate" neuropil; that is, there is no gray nucleus, only a synaptic field. This neuropil, moreover, is not exclusively optic, for it receives terminals of both the optic tract and a strong tecto-thalamic system of fibers from the roof of the midbrain. It is not a geniculate body such as we see in mammals, but it is clearly the precursor of it.

Underlying this "geniculate" neuropil is an intermediate field of neuropil which receives terminals of various lemniscus systems and tecto-thalamic tracts. It is a diffuse synaptic field into which all kinds of exteroceptive sensory impulses may be discharged. In no case do these impulses come directly from the peripheral sense organ, but always by tracts of higher order. Within the gray layer there is a third layer of neuropil (not drawn in the figure) which may be termed the periventricular neuropil. This deep neuropil is a dense entanglement of very slender collaterals and terminals of axons from various sources within which the cell bodies of all thalamic neurons are closely enmeshed.

The neurons of the sensory thalamus, accordingly, may be activated in any one or all of three ways: (1) By the periventricular neuropil, which effects synaptic junctions directly upon their cell bodies; (2) by the intermediate neuropil or "nucleus diffusus" field; (3) by the superficial or "geniculate" neuropil. Most of the neurons are related with all three of these synaptic fields; all of them are under the influence of the deep periventricular neuropil; and some of the smaller elements may send their dendrites into only one of the layers of neuropil of the white substance, *i.e.*, into the intermediate diffuse neuropil or into the superficial "geniculate" neuropil.

In the most primitive arrangement all neurons spread their dendrites in both the intermediate and the superficial optic or geniculate layers of neuropil. By suppression of one of these dendrites in some cases and the other dendrite in other cases, neurons of physiologically different connections are specialized. But the cell bodies of the two types are mingled; they are not segregated; only the neuropil of the synaptic field is localized. Next the neurons with "geniculate" connections tend to be sorted out from the others. In accordance with Kappers' law of

neurobiotaxis, their cell bodies migrate outward from the central gray toward the synaptic field containing the terminals of the optic tract. This migratory movement has begun in the frog and it is consummated in reptiles. There is a true lateral geniculate body in reptiles whose elements are specifically related with the optic and tecto-thalamic tracts and are completely emancipated from connection with the deep periventricular neuropil and the intermediate diffuse neuropil. During this process of segregation of the geniculate body the remaining gray matter of the sensory thalamus is undergoing a similar differentiation and local specialization of other types of nuclei.

In mammals the differentiation and localization of function of the lateral geniculate body has advanced another step. In amphibians and reptiles, as in mammals, the geniculate neuropil receives fibers from the optic tracts and optic tectum, the latter contained in the brachium of the superior colliculus. In these lower vertebrates fibers leave the nucleus diffusus thalami in two directions—downward toward the cerebral peduncle for thalamic reflexes and upward into the cerebral hemisphere as thalamic radiations of the internal capsule system, again as in mammals. But in amphibians and reptiles no specific optic projection tract has been described, passing from the lateral geniculate body into the hemisphere, though Crosby believes that such fibers are probably present in some reptiles. Now in mammals the lateral geniculate body is divided into a dorsal and a ventral part. The ventral part receives optic fibers and the brachium of the superior colliculus and is evidently an apparatus of visual thalamic reflexes. It is strictly comparable with the reptilian geniculate body, for no cortical projection fibers arise from it. The mammalian dorsal nucleus, on the other hand, is a new structure differentiated as the specific nucleus of origin of optic projection fibers terminating in the striate area of the cortex (Brodmann's area 17). It is this dorsal nucleus alone which in primates is greatly enlarged, with neurons arranged in thin convoluted sheets within which both retinal fields and cortical fields are precisely and minutely localized.

This in brief outline is the history of the evolution of the lateral geniculate body, its gradual emergence from a nearly homogeneous and diffuse thalamic gray, with progressive differentiation and segregation in space of neurons and related fiber tracts, until in man every spot on the retina activates a definite spot in the geniculate body, and each of these spots, in turn, registers upon a definite and sharply circumscribed area of the striate cortex, as Dr. Poljak, among others, has so clearly demonstrated.

The evolutionary history of the lateral geniculate body has been selected for description here because it presents in clear and simple outline a sequence of events which is repeated in principle in other parts of the brain. In the corpus striatum and cerebral cortex, for instance, a similar story can be clearly read; but the details are here more complicated and they have been reported elsewhere.[2]

The key to these progressive changes in histological organization is to be sought in the synaptic field, that is, in the neuropil. As in the thalamus, so elsewhere throughout the brain of the generalized Amphibia, this neuropil is arranged in three layers, deep or periventricular, intermediate and superficial.

The periventricular neuropil is spread throughout the gray layer of the entire brain as an entanglement of finest axons within which the cell bodies of all neurons are embedded. Most of these axons are collaterals of long fibers of tracts with well-defined functional specificity, but this neuropil as a whole is of uniform texture, with little evidence of local specialization. It is relatively homogeneous histologically but not physiologically equipotential, for different parts of it are locally activated from different sensory systems—olfactory in front, optic in the diencephalon and mesencephalon, and other senses farther down in the brain stem. This is obviously an integrative apparatus of major importance and probably is concerned chiefly with the most primitive types of mass-action, the regulation of general bodily tone by reinforcement and inhibition, and other generalized functions of the organism as a whole. Here localization of function is at a minimum, though it is not totally absent. This deep neuropil is entirely lacking in the pallial part of the human cerebral hemispheres, but it is more or less well developed throughout the brain stem, being seen in its most characteristic form in the periventricular gray of the thalamus.

In the Amphibia the intermediate level of neuropil is the principal synaptic field. Here the nervous connections are made which serve the standardized mass-movements and local reflexes of locomotion, feeding, etc., and here are the long tracts of fibers which connect the local centers involved. Such incomplete localization of function as these animals exhibit is effected chiefly in this zone of neuropil, and the elaboration of local gray centers or nuclei follows the differentiation of special synaptic areas within this zone.

[2] C. Judson Herrick, "The Amphibian Forebrain." VI. "Necturus," *Jour. Comp. Neur.*, Vol. 58, No. 1, 1933; VII. "The Architectural Plan of the Brain," *ibid.*, Vol. 58, No. 2, 1933; VIII. "Cerebral Hemispheres and Pallial Primordia," *ibid.*, Vol. 58, No. 3, 1933; IX. "Neuropil and Other Interstitial Nervous Tissue," *ibid.*, Vol. 59, No. 1, 1934; X. "Localized Functions and Integrative Functions," *ibid.*, Vol. 59, No. 2, 1934.

The superficial or marginal zone of neuropil is everywhere present, but in most cases very simply organized. Where it is locally specialized, as in the "geniculate" neuropil, it is composed chiefly of collaterals of long tracts whose fibers make their primary connections elsewhere. In other words, it is subsidiary to the main trunk lines of reflex connection. The deep neuropil is also a subsidiary, or collateral, connection of the long tracts, but without well-defined local areas of specialization. In contrast with this, the specialized superficial areas are more or less definitely localized and each of them receives its own characteristic complex of collateral connections. In brief, the superficial areas of neuropil seem to be well adapted for conditioning of reflexes, and this is probably the rôle which they play.

In the pallial part of the amphibian cerebral hemisphere there is no differentiated cerebral cortex, though primordia of the principal cortical areas can be recognized. In this primordial pallium the three zones of neuropil tend to converge into a single field which pervades the whole thickness of the wall of the hemisphere, and this fusion is more advanced in proportion as the cortical type of organization of the gray substance is approached.

We have here a prodromal stage of cortical differentiation in which all three types of nervous organization which characterize the brain stem are represented—(1) the primitive, relatively non-specific and poorly localized integrative apparatus serving generalized totalizing functions, (2) the apparatus of local reflexes and (3) the mechanisms of conditioning. In further differentiation of the cortex these factors are all preserved, though in anatomical and physiological patterns of organization which are unique and found nowhere else in the nervous system.

In the amphibian pallial primordia there is some localization of function determined by the anatomical arrangement of projection fibers of diverse subpallial connections, but this localization is at a minimum. This pallium obviously acts mainly as a whole to influence nervous activities whose patterns are determined in subpallial territory; that is, its chief functions are the differential inhibition or reinforcement of brain stem activities as going concerns.

With further elaboration of cortical structure in reptiles and mammals and with the segregation in space of specific sensory and motor projection tracts of the internal capsule system, progressively more precise localization of function appears in those cortical fields which are anatomically related with these systems of projection fibers. At the same time the non-specific integrative, activating and associational apparatus increases in still greater amount.

In lower mammals the apparatus of the totalizing functions is mingled with that of the sensory and motor projection systems, and this remains true to a large extent even in man. As we pass from lower to higher primates the apparatus of projection becomes more and more segregated from the far more elaborate apparatus of association, conditioning and rational control, though in the nature of the case this separation is never complete. The so-called associational cortex is differentiated in two directions: (1) There is local differentiation of cell types, lamination patterns and tracts of association fibers which serve stable innate or acquired patterns of behavior or mental processes; this is the permanent organization or architectonic of the hemisphere. (2) There is also a very large amount of unspecialized nervous tissue which infiltrates the permanently organized connections of projection and associational systems and is itself non-specific and labile in structure and function. This non-specific tissue may be very complex structurally, composed in part of small neurons and in part of collateral connections of neurons whose primary connections are those of the stable systems of projection and association tracts. This labile tissue of the second type has no fixed or permanent structurally predetermined reaction patterns of its own; it can be activated only through the nervous elements of the first type; but it pervades the entire cortical organization, and activation of the cortex in any place will affect it more or less extensively. It is a permanent integrator, and it is more than this. Not being a part of the stable architectonic, it possesses a characteristic fluidity. The pattern of its activity at any moment is determined, not by fixed structural connections, but by dynamic factors which are as yet obscure. These transient patterns of activation have no permanent localization.

The human cerebral cortex, then, exhibits three types of localization of function. The first is in the projection areas, which can be mapped in mosaic patterns on the surface. These are determined primarily by their respective subcortical connections. Probably all parts of the cortex have some subcortical connections, but the principal systems of projection fibers are related with specific and clearly defined cortical areas. The second type is an expression of the architecture of the intracortical association systems. These stable arrangements of cell bodies and related association fibers constitute the apparatus of our standardized patterns of behavior and mental activity. This apparatus is present throughout the cortex. The functions performed by it are more or less permanently localized, but the pattern of this localization is very intricate and it can not be projected upon the surface of the brain in mosaic designs like those of the projection centers. Third, in addi-

tion to the localized systems of projection and associational neurons, there is in the cortex an enormous mass of non-specific tissue. This is everywhere abundant; it varies in structure from place to place and in function from moment to moment. It integrates all cortical activities, synthesizes experience and provides the plasticity of structure requisite for learning and higher mental processes in general.

Reviewing what is known of the phylogeny of the cerebral cortex, it appears that the integrative, associational and synthetic functions have predominated from its inception. Some measure of localization is always present. Only the analytic functions of the projection systems can be charted in mosaic patterns. The segregation and separation in space of the data derived from diverse sensory experiences seems to be an essential prerequisite for the association and synthesis of these experiences and their conversion into appropriate patterns of response. In lower mammals the localization of systems of projection and stable patterns of association is far less refined than in man and the mass-action of the cortex bulks larger. The more refined localization of these two types in the human brain is of great significance in clinical neurology and especially in surgery. The elaboration of these localization patterns goes hand in hand with a still greater increment in the poorly localized synthetic and integrative functions. It is these latter which have most significance for psychology and psychiatry.

The evolutionary history of the lateral geniculate body shows how a highly specific pattern of localization has gradually emerged from a diffuse and non-specific arrangement. The totalizing functions of correlation and integration have not been impaired by this process of local differentiation; on the other hand, they have been amplified and special apparatus has been elaborated (chiefly in the cerebral cortex) to ensure their progressive enhancement and to maintain their dominance over all other components of the behavior pattern.

The evolutionary history of those sensory-motor systems, like the olfactory and auditory, where precise localization in space is not an important factor, presents a radically different morphological picture, the details of which can not here be entered into.

Some cerebral functions are very precisely localized, as every clinical neurologist knows. Having determined the exact pattern of this localization for some one sensory-motor system, the clinician or the experimentalist is inclined to generalize and try to fit all his experience into this pattern. But a point is soon reached where this attempt breaks down. The observed facts do not fit the pattern. The functions performed are extremely diverse. Some of these functions are performed by local areas of gray that can be charted on the surface in mosaic patterns, like the projection fields of the cortex. These fields are interconnected by a complex web of fiber tracts which are stable structural features; these also are localized in space, though in patterns which can not be charted on the surface in mosaic designs. And permeating all this stable architectural fabric there is an enormous mass of neuropil and other less specific tissue whose structure is generalized and whose functions are more labile and modifiable.

This interstitial nervous tissue serves the primitive integrative or totalizing functions and also correlation and conditioning of reflexes and all higher mental processes, including the semantic or symbolic activities. This type of tissue is highly elaborated in the cerebral cortex. It is not structurally homogeneous or physiologically equipotential, yet it has no stable patterns of anatomical localization comparable with those of reflex arcs or cortical projection centers. The pattern of performance varies from place to place and from time to time. But this pattern is not self-determined; for its action at any moment depends on the structural organization and physiological activation of the more stable tissues with which it is organically related.

It is evident, accordingly, that no single formula of cerebral localization of function can be written. Each type of performance has its own anatomical pattern which must be discovered by patient research. For some types of function there are no local organs with stable or rigid arrangements of neurons, for these organismic or totalizing activities are general in their reach and fluid in character. Yet the tissues which perform them are not structurally homogeneous or physiologically equipotential. In these integrating functions the amount of tissue activated is a factor in the situation, as Lashley has shown, but diversification of structure and of pattern of activation is essential, for this is the apparatus of our mental life in both its analytic (sensory) and its synthetic (rational) aspects.

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